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of the

Torrey Botanical Club

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SCIENCE

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THE OLDEST BOTANICAL JOURNAL OF THIS HEMISPHERE
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BULLETIN OF THE TORREY BOTANICAL CLUB

VOL. 88, No. 3, pp. 143–152 MAY, 1961

Notes on Some Grasses. XII. Affinities of *Gouinia*[1]

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TATEOKA, TUGUO. (U. Montreal, Canada.) Notes on some grasses. XII. Affinities of *Gouinia*. Bull. Torrey Bot. Club 88(3): 143–152, 1961.—Leaf anatomy and epidermis of 12 species of *Gouinia* are examined. The results, together with morphological traits, are described. *Gouinia* is clearly different from Arundineae and is closely related to the chloridoid grasses in morphological, anatomical, and histological features. In connection with the systematic position of *Gouinia*, the delimitation of Arundineae is discussed, and the genera *Arundo, Cortaderia, Gynerium, Lamprothyrsus, Phragmites, Hakonechloa, Moliniopsis, Molinia* and *Crinipes* are referred to this tribe. It is concluded that *Gouinia* may be most naturally placed in Chlorideae-Eragrostinae.

The grass genus *Gouinia* was first described by Bentham and Hooker in 1883 although they credited this genus to Fournier who effectively published his paper in 1886 (Mex. Pl. 2: 103). No species was given by Bentham and Hooker, but Fournier described the species *G. polygama* (*G. virgata*). Swallen (1935) revised this genus taxonomically, and enumerated 13 species which are distributed in the tropical and subtropical regions of the New World.

Gouinia has usually been ascribed to Chlorideae-Eragrosteae. Bews (1929), Swallen (1935), Hitchcock (1936), Parodi (1946), a.o., referred *Guoinia* to Chlorideae, advocating the affinity of this genus to *Diplachne, Leptochloa*, etc. These genera were moved to Eragrosteae by Hubbard (1936). Although the members of Eragrosteae and Chlorideae are usually separated in a tribal rank, their mutual affinity is evident. In contrast to the view mentioned above, *Gouinia* has been placed in Arundineae by some authors (Bentham and Hooker, 1883; Pilger, 1954). Two opinions have thus been presented as to the systematic position of *Gouinia*. The present paper aims to dissolve this disparity through morphological, anatomical and histological studies.

Morphological attributes and leaf structures of *Gouinia*. Leaf anatomy and histology of *Gouinia* have been completely neglected in previous studies. My examinations of these characters were made on the leaves of dried her-

[1] I wish to express my cordial thanks to Dr. Áskell Löve and Dr. Doris Löve, who very kindly helped me in many ways. I am also grateful to the head curator of the United States National Herbarium, Dr. J. R. Swallen, for the use of herbarium specimens. To the National Research Council of Canada, I am indebted for the financial support which made this study possible.

[The BULLETIN for March–April 1961 (88: 77–142) was issued July 17, 1961.]

barium specimens, listed in Table 1. The leaves were macerated in cold water.

TABLE 1. *List of species and file numbers of specimens (U. S. Nat. Herb.) whose leaf anatomy and epidermis were examined.*

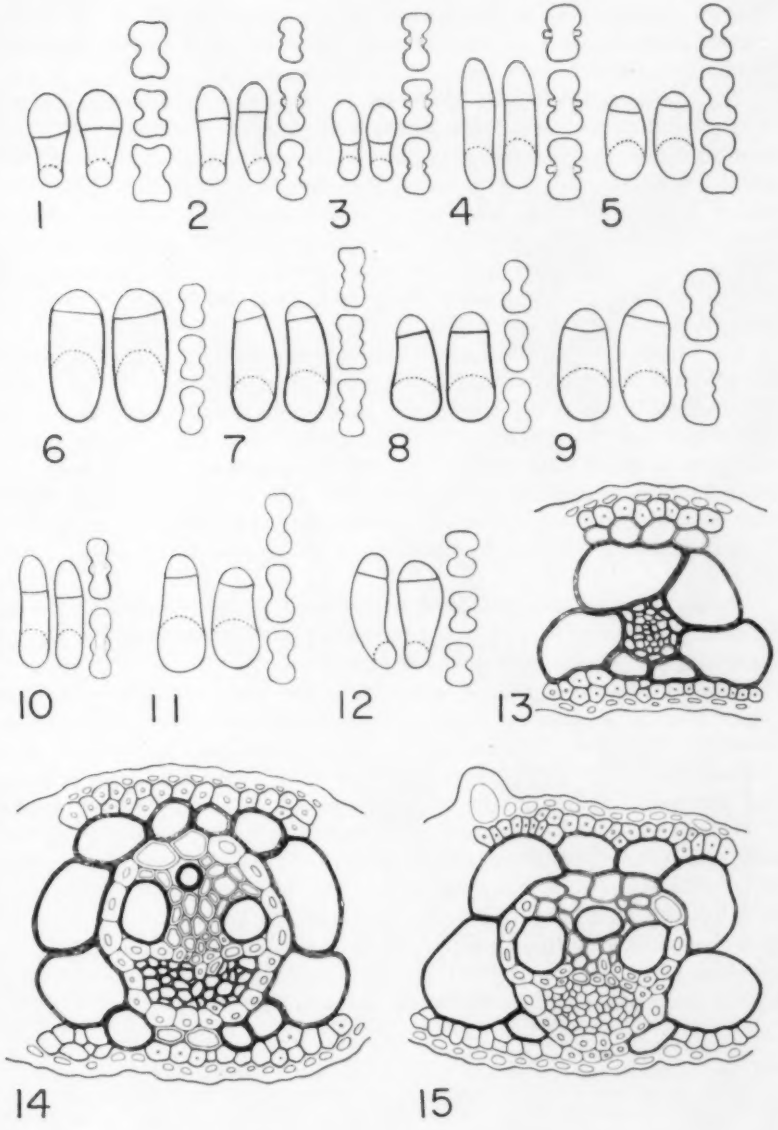
Species	File number of specimens	Species	File number of specimens
Gouinia gracilis Ekman	without number	*G. mexicana* Vasey	481015
G. virgata Scribn.	1296948	*G. longiramea* Swallen	1867532
G. brasiliensis Swallen	1983723	*G. latifolia* Vasey	1819994
G. barbata Swallen	1613613	*G. cearensis* Swallen	1613316
G. papillosa Swallen	747935	*G. guatemalensis* Swallen	1869122
G. ramosa Swallen	1914729	*G. paraguayensis* Parodi	1819542

After soaking over night, they were sectioned by hand with a razor blade. The descriptions presented below are based on the survey of previous literature and my examinations of the herbarium specimens in the National Herbarium of the United States in Washington.

(1). Gross morphology: Perennial grasses with simple or branching culms and terminal panicles of slender, one-sided, simple or rarely compound racemes. Culms tufted or simple, 30–300 cm. tall, usually erect. Sheaths usually more or less pilose, papillose, papillose-pilose, scabrous or scaberulous, rarely glabrous. Blades flat, rarely involute, often sparsely pilose on the upper surface near the base. Ligules 1 mm. or less long, membranaceous, erose or rarely ciliate. Panicle erect or drooping, branches usually spreading.

(2) Spikelet morphology: Spikelets 2- to several-flowered, disarticulating above the glumes and between the florets, the uppermost one reduced to a sterile, awned rudiment or, rarely, to a bristle. Glumes acute, or sometimes obtuse, the first a little shorter than or nearly equal to the second, both shorter than, rarely subequal to or longer than, the lemma, the first glume 1–5-nerved (usually 1–3-nerved), the second 1–7-nerved. Rachilla scabrous or scaberulous near the base of the next floret, rarely glabrous, hairless. The base of the floret more or less pubescent. Lemmas lanceolate, 3-nerved, the side nerves being near the margins, very rarely 5 (–7)-nerved, the tip usually acuminate, bidentate or entire, the awns erect, arising from the tip or the sinus of the minute teeth, densely pubescent on both sides of the midrib and near the margins for about half the length, the latter area rarely glabrous or nearly so. Palea equal to or a little shorter, rarely much shorter or a little longer, than the lemma, 2-keeled, toothed, the teeth sometimes aristate, the margins glabrous or pubescent.

Figs. 1–12. Bicellular microhairs (left) and siliceous cells (right) in leaf epidermis of *Gouinia*. 1–11, lower epidermis. 12, upper epidermis. ×450. 1, *G. gracilis*. 2, *G. virgata*. 3, *G. brasiliensis*. 4, *G. papillosa*. 5, *G. ramosa*. 6, *G. mexicana*. 7, *G. latifolia*. 8, *G. cearensis*. 9, *G. guatemalensis*. 10, *G. longiramea*. 11, *G. paraguayensis*. 12, *G. barbata*. Figs. 13–15. Trans-sections of leaf blades of *Gouinia*. ×450. 13, *G. brasiliensis*. 14, *G. mexicana*. 15, *G. longiramea*.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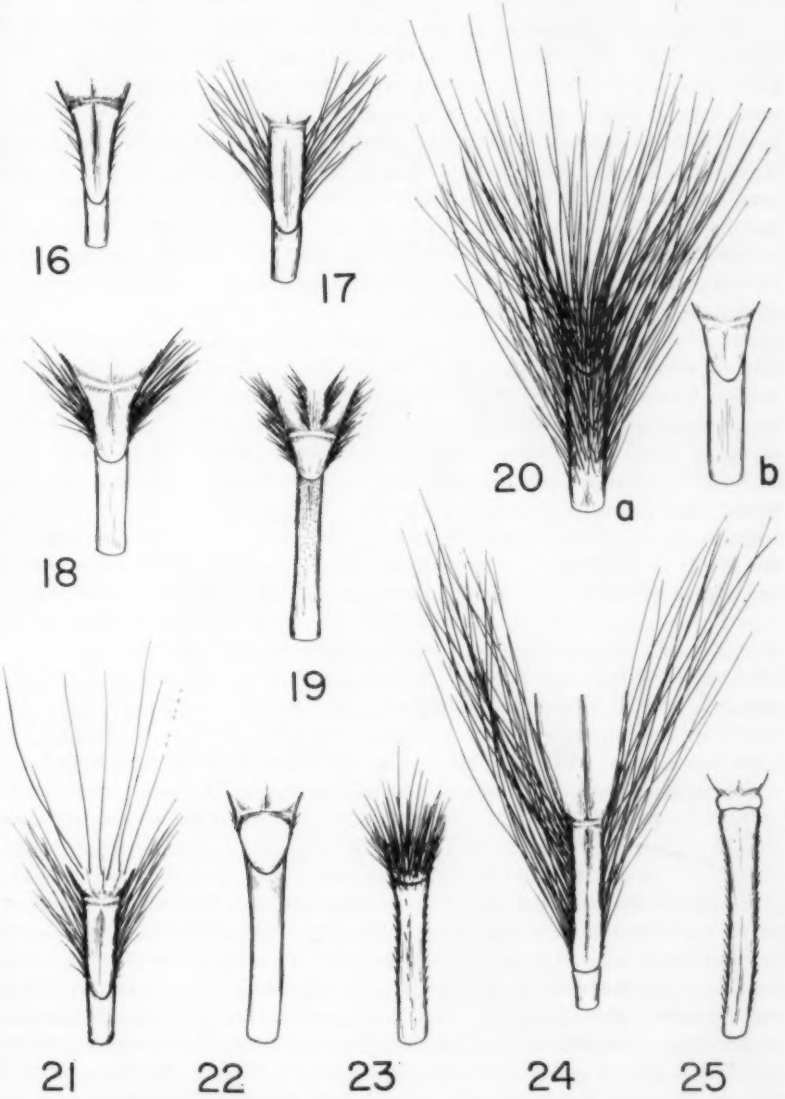
(3) Flowers and caryopses: Lodicules two, cuneate, truncate, hairless. Ovaries glabrous, two styles distinct, arising from the tip of the ovary, stigmas dark-purple. Caryopses usually dark-brown and having style remnants, the embryo $\frac{1}{5}$–$\frac{1}{3}$ the length of the caryopsis.

(4). Leaf epidermis: All 12 species observed have bicellular microhairs in the leaf epidermis. Microhairs mostly bullet-shaped. The upper cell, whose membranes are somewhat thinner than, or similar to, those of the lower cell, usually much shorter than the lower. However, in a few species (*G. gracilis* and *G. brasiliensis*), the upper cell is nearly equal to, or somewhat longer than, the lower. Siliceous cells of dumbbell, or modified dumbbell shape in both the lower and upper epidermis of all species observed. Stomata mostly oval in outline. When long hairs are present, they always carry a sheath of epidermal cells at the base. (Figs. 1–12).

(5). Leaf anatomy: Vascular bundles surrounded by a well developed parenchyma sheath consisting of large cells with abundant chloroplasts. Chloroplasts found in the parenchyma sheath cells usually different in color and shape from those scattered in the mesophyll cells. Inner bundle sheath, composed of small thick-walled cells, well developed around the large vascular bundles, but in the small vascular bundles weakly developed. Motor cells well developed throughout the species observed. These anatomical features fit Brown's (1958) chloridoid type of leaf anatomy of grasses . (Figs. 13–15).

Remarks on certain genera of Arundineae. Before considering the relationship between *Gouinia* and Arundineae, a short discussion is needed regarding the constituents of Arundineae.

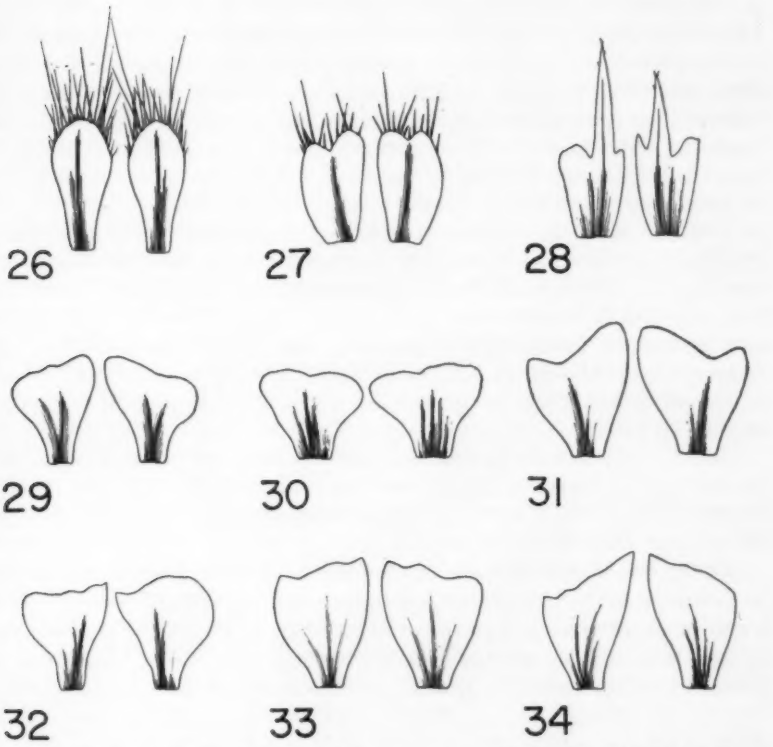
It should be noted that Arundineae in the sense used in the present paper does not include the genera *Ampelodesmos* and *Neyraudia*. The remarkable difference of *Ampelodesmos* from Arundineae has already been disclosed by Reeder (1957) in his studies of embryo anatomy. *Ampelodesmos* has festucoid features in this respect, whereas *Arundo*, *Phragmites* and *Cortaderia* show the arundinoid-danthonidoid type. In morphological features, *Ampelodesmos* differs from Arundineae by the hairy ovary, indistinct styles (the styles of *Lamprothyrsus* are also indistinct), flat stigma axis, rachilla with long silky hairs (Fig. 20) and the number of lodicules. In their preliminary outline for a new system of classification of the Gramineae, Stebbins and Crampton (1959) placed *Ampelodesmos* in Festucoideae as an independent tribe. This treatment seems to be natural.



Figs. 16–25. The segment of rachilla between the first and second florets and the base of the second floret. 16, *Gynerium sagittatum* Beauv. (pistillate spikelet). 17, *Cortaderia selloana* Aschers. and Graebn. (pistillate spikelet). 18, *Neyraudia madagascariensis* Hook.f. 19, *Gouinia virgata* Ekman. 20, *Ampelodesmos mauritanicus* Dur. and Schinz; a, actual appearance; b, with hairs removed to show the relative length of the rachilla and the floret base. 21, *Lamprothyrsus peruvianus* Hitchc. 22, *Arundo donax* L. 23, *Moliniopsis japonica* Hayata. 24, *Phragmites communis* Trin. 25, *Molinia caerulea* Moench.

Opinions are divided as to the systematic position of *Neyraudia*. Most authors (Bews, 1929; Ohwi, 1942; Hitchcock and Chase, 1951; Keng et al, 1957; a.o.) have placed *Neyraudia* near *Phragmites*, *Cortaderia*, etc., but some authors (Hubbard, 1936; Pilger, 1954; a.o.) ascribe it to Eragrosteae. In spikelet morphology *Neyraudia* represents an intermediate between Arundineae and Eragrosteae. The floret base of *Neyraudia* is considerably lengthened and hairy (Fig. 18), as is often the case in the genera of Arundineae, and its 3-nerved lemmas with long hairs near the margins are very similar to those of the pistillate floret of *Gynerium*. Tateoka (1956a) assigned *Neyraudia* to Arundineae as he found panicoid bicellular microhairs in its leaf epidermis. But this view was opposed by Conert (1959), who revised the species of *Neyraudia* and referred the genus to Eragrosteae. The basis of his reference was found in the spikelet morphology and leaf structure of *Neyraudia*. The significance of the bicellular microhairs in grass systematics was recently reexamined by Tateoka, Inoue and Kawano (1959), and they disclosed that the different types of bicellular hairs, i.e. panicoid and chloridoid, are sometimes not correlated with the systematic grouping. This recent observation contradicts Tateoka's (1956a) earlier opinion that the features of microhairs found in *Neyraudia* do not permit its reference of this genus to Eragrosteae. Considering such features shared by *Neyraudia* and Eragrosteae as the cuneate lodicules and the well developed parenchyma sheath cells with abundant chloroplasts, this genus appears to fit naturally into Eragrosteae (Chlorideae-Eragrostinae). It seems desirable, however, to examine this problem further by studying chromosomes, embryo anatomy, etc., of *Neyraudia*, in order to confirm whether or not other common features shared by *Neyraudia* and Arundineae, such as the lengthened floret base and long-hairy lemma, can be attributed to parallel development.

There are some other much discussed genera, e.g., *Molinia* which I still prefer to retain in Arundineae even though they differ in various features from the other members of this tribe. The lodicules of *Molinia* are cuneate, the base of its floret is glabrous and not lengthened, and the basic number of chromosomes is 9. In the (true) Arundineae, the lodicules are usually more or less elongated (Figs. 26–28), the lemmas and the lengthened floret base are often long silky hairy, and the basic numbers of chromosomes are 12 (6) and 5. Hubbard (1948) tentatively referred *Molinia* to Danthonieae, and Hylander (1953) treated it as a separate tribe. Although *Molinia* is apparently rather remote from the main constituents of Arundineae, there exist a few genera which show some similarity to *Molinia* on one hand and resemble the (true) Arundineae on the other. *Moliniopsis*, which is distributed in East Asia, is related to *Molinia* in gross morphology as well as in spikelet and flower characters on one hand, but on the other it shares various common features with *Hakonechloa* whose single species is endemic in Central Japan. The two genera have the same basic chromosome number ($x = 5$),



Figs. 26–34. Lodicules. 26, *Lamprothyrsus peruvianus* Hitchc. 27, *Cortaderia selloana* Aschers. and Graebn. 28, *Arundo pliniana* Turra. 29, *Gouinia guatemalencsis* Swallen. 30, *G. virgata* Ekman. 31, *G. paraguayensis* Parodi. 32, *G. barbata* Swallen. 33, *Leptochloa uninervia* Hitchc. and Chase. 34, *Diplachne serotina* Link.

similar traits of leaf structure and some resemblance in flower features. Meanwhile *Hakonechloa* shows resemblance in spikelet features to *Phragmites*. The lemma of *Hakonechloa* is long-hairy near the margins as often found in other genera of Arundineae, and its floret base is lengthened and long-silky-hairy like that of *Phragmites*. Further studies are needed for the exact understanding of the systematic relationship of these grasses. *Molinia* is here tentatively retained in Arundineae, although this position seems to be rather anomalous for this genus.

Opinions are also divided as to the systematic position of *Lamprothyrsus*. Hitchcock (1927) mentioned that this genus is related on one hand to *Danthonia* and on the other to *Cortaderia*. *Lamprothyrsus* has the 2-lobed lemma with a long and twisted spreading awn which suggests the affinity

of this genus to *Danthonia*, and Parodi (1949) and others have placed *Lamprothyrsus* in Danthonieae, which is apparently close to Arundineae. On the other hand, the 1-nerved hyaline glumes, the lengthened and hairy floret base (Fig. 21), and the large and many-flowered panicle of *Lamprothyrsus* suggest its relationship to Arundineae. Further studies seem to be needed in order to ascertain the natural classification and the definition of tribes in arundinoid-danthonidoid grasses. *Lamprothyrsus* is here retained in Arundineae according to Pilger (1954).

Crinipes, which is distributed in Africa, is also ascribed to Arundineae by Pilger (1954). De Wet (1960) examined the embryo anatomy, leaf anatomy and histology of *Crinipes*, and mentioned that tropical species of the genus should be referred to Arundineae whereas South African species may be closer to Danthonieae. Taxonomic revision of *Crinipes* species seems to be needed, although its affinity to the arundinoid-danthonidoid grasses is not questioned. *Crinipes* is here also retained in Arundineae according to Pilger (1954).

The constituents of Arundineae whose relationship with *Gouinia* will be discussed in the next chapter are thus limited to the following genera: *Arundo, Cortaderia, Gynerium, Lamprothyrsus, Phragmites, Hakonechloa, Moliniopsis, Molinia* and *Crinipes*.

Characters which distinguish Gouinia from Arundineae. Arundineae, as defined above by the list of genera included in it clearly shows various conspicuous differences from *Gouinia*. Evidence from the leaf anatomy and epidermis of the two groups contradicts their relationship. According to Brown (1958), *Arundo, Phragmites* and *Cortaderia* are included in his arundinoid type of leaf anatomy. Tateoka (1956b) has reported that *Arundo, Phragmites, Cortaderia, Hakonechloa, Moliniopsis* and *Molinia* are more or less closely related in leaf anatomy and epidermis. De Wet (1960) has also mentioned that the tropical species of *Crinipes* are very close to Brown's (1958) arundinoid type in leaf anatomy. All these genera lack the mass of chloroplasts in the cells of the parenchyma sheath, but the chloroplasts are uniformly distributed in the mesophyll cells. *Gouinia*, however, has abundant chloroplasts in the parenchyma sheath cells like the chloridoid genera. The bicellular microhairs of *Gouinia* are bullet-shaped throughout the species observed, and its upper cell is usually shorter than the lower. This type of microhairs suggests not only the affinity of *Gouinia* to chloridoid genera but also its distinction from Arundineae which is characterized by rod-like microhairs (Tateoka, 1956b).

The morphology of *Gouinia* also has various features different from that of Arundineae. The lodicules of Arundineae are usually more or less elongated and sometimes hairy (Figs. 26–28), but those of *Gouinia* are cuneate, truncate and hairless (Figs. 29–32). As shown in Figs. 29–34, *Gouinia* is

very similar to *Diplachne* and *Leptochloa* in lodicule features. The lodicules of *Molinia* have some resemblance to those of *Gouinia, Diplachne* and *Leptochloa,* but *Molinia* is quite different from the latter genera in leaf anatomy and epidermis. The lemmas of Arundineae are hairy or glabrous. When hairy, the hairs are long and silky and arise from the entire or lower surface of the lemma or only from near its margins. In *Gouinia,* the lemmas are hairy, but the hairs are not so long and are found on both sides of the midrib and on the outer side, sometimes both sides, of the lateral nerves, or rarely only on both sides of the midrib. The pattern of hair development on the *Gouinia* lemmas is thus similar to that of various chloridoid genera, such as *Tridens, Heterocarpha,* etc. Except for *Molinia, Moliniopsis, Arundo* and *Crinipes,* all other genera of Arundineae are characterized by the considerably lengthened floret base as shown in Figs. 16–17, 21 and 24, and the florets disarticulate below this lengthened base which often has long-silky hairs. The segments of the rachilla are short and glabrous. This characteristic is most conspicuous in *Phragmites* (Fig. 24), in which the lengthened floret base reaches about four times the length of each segment. In this respect, *Gouinia* is different from these grasses as species of *Gouinia* do not have such a remarkably lengthened floret base but do have long rachilla segments (Fig. 19).

Considering the above mentioned morphological, anatomical and histological differences, *Gouinia* does not seem to be related to Arundineae.

Conclusion: Systematic position of Gouinia. Morphological, anatomical and histological features of *Gouinia* as described above clearly show its close affinity with chloridoid genera. The lemmas of *Gouinia* have three nerves (except *G. longiramea*), the side nerves being near the margins, as common in most chloridoid genera. The lodicules of *Gouinia* are cuneate and truncate, the styles are distinct and the stigmas are dark-purple. These features also fit with Chlorideae-Eragrosteae. This view is further supported by studies of the leaf epidermis and anatomy, because *Gouinia* shows chloridoid features also in these characters. Núñez (in Parodi, 1946) has counted $2n = 40$ in *G. latifolia.* The basic chromosome number of $x = 10$, which is the most common in Chlorideae-Eragrosteae, is also indicated for this genus.

Eragrosteae and Chlorideae are separated by some features in spikelets and inflorescences. In the former, the spikelets are two- to many-flowered, mostly hermaphroditic, pedicelled in open or contracted panicles, or secund and sessile, even subsessile, in spikes or spike-like racemes. In Chlorideae, the spikelets are one- to few-flowered with one floret hermaphroditic, and with or without an imperfect floret, sessile or subsessile in one or two rows on one side of the rachis of solitary, digitate or scattered spikes or spike-like racemes. Beside these differences, the two groups are so closely related that they may be included in the same tribe. Not only in various non-morphological features but also in such morphological features as appear in the flow-

ers themselves and the lemmas, the two groups share much resemblance. Therefore, I would like to follow Ohwi's (1942) treatment, according to which the members of the two groups and also those of Sporoboleae are united under the name of Chlorideae and each treated as subtribes, Eragrostinae, Chloridinae and Sporobolinae. If emphasis is placed upon characters of the inflorescence, *Gouinia* might be closer to the genera of Chlorideae as pointed out by Swallen (1935). *Gouinia* species have, however, spikelets with two- to several-hermaphroditic florets, and may therefore be most naturally placed in Chlorideae-Eragrostinae.

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BULLETIN OF THE TORREY BOTANICAL CLUB

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Recognition of *Elymus sibiricus* L. from Alaska and the District of Mackenzie[1]

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BOWDEN, WRAY M. and W. J. CODY (Pl. Res. Inst., Canada Dept. Agric., Ottawa.) Recognition of *Elymus sibiricus* L. from Alaska and the District of Mackenzie. Bull. Torrey Bot. Club 88(3): 153–155. 1961. Specimens of *Elymus sibiricus* L. from Alaska and the District of Mackenzie can be readily distinguished from *E. canadensis*, *E. hirsutus* and *E. glaucus*, particularly by the short glumes with short awns.

A collection of *Elymus, Cody & Matte 8668* from Fort Simpson, District of Mackenzie, did not fit any of the known species of *Elymus* from Western Canada, although it had a vague resemblance to *E. canadensis* L., *E. hirsutus* Presl. and *E. glaucus* Buckl. The specimens had long spikes, greenish-purplish spikelets, and short narrow glumes with short awns.

After some futile attempts to identify the collection, it was recalled that the Fort Simpson specimens resembled a paratype of *E. pendulosus* (*Hodgson 235, DAO*). This species was described by Hodgson (1956) because he considered that specimens from south central Alaska should not be identified as *E. canadensis* L. Examination of the specimens showed that *Cody & Matte 8668* was indeed the same species as *E. pendulosus*. It was also the same species as three Alaskan specimens in the Plant Research Institute Herbarium (DAO) and the same as five Alaskan specimens in the National Museum of Canada (CAN), all previously identified by various botanists as *E. canadensis* L.

Because the distribution pattern seemed unusual, J. A. Calder, a colleague, suggested that specimens of the Siberian species of *Elymus* should be compared with these collections. The key and description in Nevski (1934) were used and all of the specimens proved to be *Clinelymus sibiricus* (L.) Nevski. However, this species has to be called *Elymus sibiricus* L. since it is the type species of the genus *Elymus* L. (addendum of Bowden, 1957).

The significant synonymy can now be stated:

Elymus sibiricus L., Sp. Pl., ed. 1, Vol. 1: 83. 1753.

Clinelymus sibiricus (L.) Nevski, Bull. Jard. Bot. Acad. Sci. URSS, 30: 641. 1932.

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Elymus pendulosus Hodgson, Rhodora 58: 144–148. 1956.

Elymus canadensis auct., *non* L.; also on specimen labels.

Elymus sibiricus L. has a wide range from the European part of the U.S.S.R. to Kamchatka. The Alaskan and District of Mackenzie specimens resemble a specimen of *E. sibiricus* from Novosibirsk (DAO). They also resemble a large number of cultivated specimens (DAO) that were grown from numerous seed sources. Five of the seed accessions were from the U.S.S.R. Hodgson (1956) listed the chromosome number of *E. pendulosus* as $2n = 28$. The same chromosome number has been determined on two of our cultivated collections of *E. sibiricus:* No. 805 S2 (not S1) from Uppsala, Sweden and No. 347 S1 from Kew.

The specimens of *E. sibiricus* from Alaska and the District of Mackenzie generally have the morphological characteristics described by Nevski (1934). All of the specimens consistently have the following characteristics: culm nodes dark; spikelets (1)-2-(3) per rachis node, greenish-purplish or greenish; glumes linear or linear-subulate, rarely slightly broadened, short, the glume bodies, 0.3–0.5-(0.8) cm. long, with short awns, 0.1–0.65 cm. long; lemmas lanceolate, scabrous to scabrid on the backs; first lemma bodies, 0.8–1.1 cm. long, with awns, 1.0–2.5 cm. long; paleas bidentate at the apices, short-ciliate on the keels. Nevski (l.c.) described the plants as glaucescent but this characteristic is not pronounced in any of the specimens from Alaska and the District of Mackenzie. There is variation in spike length, (7.0)–15.0–(30.0) cm. long, but many specimens have quite long spikes. Nevski described the leaf blades as "scabrous on both surfaces, sometimes slightly hirsute on the upper surface." All of the specimens from Alaska and the District of Mackenzie have rows of white hairs on the nerves of the upper leaf-blade surfaces.

Voucher specimens examined of *Elymus sibiricus* L.: District of Mackenzie: A few plants on open grassy bank of Mackenzie River, upstream from Hudson Bay Co., Fort Simpson, *W. J. Cody & J. M. Matte 8668, July 8, 1955* (two sheets, DAO). Alaska: West shore Knik Arm-S Fish Creek, 61°4′N, 149°8′W, *H. J. Hodgson 235* (DAO), paratype of *E. pendulosus* Hodgson. On sand dune, Palmer, *Dutilly, Lepage & O'Neill 21, 872* (DAO). Sand-drift along the road, Palmer, *Dutilly, Lepage & O'Neill 21, 872* (CAN). On railroad, Eklutna, *Dutilly, Lepage & O'Neill 20, 699* (DAO, CAN). Between Anchorage and Palmer, *Dutilly, Lepage & O'Neill 21, 248* (DAO). Palmer, *Dutilly, Lepage & O'Neill 21, 248* (CAN). Along railroad track, Talkeetna, *J. P. Anderson 7622* (CAN). Roadside, Glenn Highway 52, *J. P. Anderson & R. G. Brown 10, 167* (CAN). Hodgson (1956) noted that he had deposited other specimens (as *E. pendulosus*) in various herbaria and additional Alaskan specimens of *E. sibiricus* can be expected to be filed under *E. canadensis*.

One wonders if the District of Mackenzie specimens of *E. sibiricus* are native or recently introduced. Hodgson (1956) discussed this problem in relation to the Alaskan collections and expressed the opinion that the species appeared "to be indigenous to south central Alaska."

Another specimen from the District of Mackenzie appears to be *Elymus sibiricus* L. f. *monostachyus* Hultén (see Hultén, 1927). The specimen is: District of Mackenzie: Dry ridge, burnt over in 1943, Liard River, at mouth of Nahanni River, *F. S. Nowosad 3, July 19, 1944* (DAO). It differs from the other specimens of *E. sibiricus* in that there is only one spikelet at each rachis node, except for one node which has two spikelets. Hultén (1927) named the one-spikelet form as "f. *monostachyum*". He listed *Agropyron confusum* Rosh. as a synonym and a specimen from Nerchinsk (DAO) under this name appears to be the same as f. *monostachyus*. The Nerchinsk collection has short narrow glumes but the lemma backs are glabrous toward the bases, not scabrid as in all of the other specimens of *E. sibiricus*, including *Nowosad 3*. However, the Nerchinsk specimen may be slightly atypical since Nevski (1934) described the lemmas as scabrous (under *Roegneria confusa*).

In conclusion, specimens of *Elymus sibiricus* L. from Alaska and the District of Mackenzie can be readily distinguished from *E. canadensis*, *E. hirsutus* and *E. glaucus*, particularly by the short glumes with short awns.

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BULLETIN OF THE TORREY BOTANICAL CLUB

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The vegetation of the William L. Hutcheson Memorial Forest, New Jersey

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MONK, CARL D. (U. Florida, Gainesville.) The vegetation of the William L. Hutcheson Memorial Forest, New Jersey. Bull. Torrey Bot. Club 88(3): 156–166. 1961.—The upland portion of the Hutcheson Memorial Forest (82% of the area) is dominated by white oak, black oak, red oak, and red hickory. These species form an almost continuous canopy about 95 ft. in height. Beneath the canopy is a pronounced dogwood understory. The shrub layer is characterized by maple-leaved viburnum. The herb layer is best developed in spring when May-apple is abundant. The poorly drained areas are dominated by white oak, white ash, red maple, and pin oak. Recent wind damage has created many openings in the canopy. The understory is not as distinct as it is on the better drained soils. Transgressives of red maple are the principal components. The shrub layer is characterized by arrowwood, spicebush, and greenbrier. Spotted touch-me-not and skunk cabbage are the principal herbs. Hutcheson Memorial Forest is a variant of the oak-hickory forest type complex of the Piedmont, but it does not have the climax status which this community exhibits on the southern Piedmont. Openings in the forest resulting from occasional severe windstorms or other catastrophe are closed again by a process in which local old field species play a minor role in the re-establishment of typical forest structure and composition. Red maple and white ash, much more often than oaks and hickories, are the tree species that in the recent past and at present are destined to fill the gaps in the canopy.

The William L. Hutcheson Memorial Forest is 65 acres in extent and is located on the Piedmont of New Jersey (40°30′N, 74°34′W). It is a mature oak forest (Buell 1957). A study of growth rings has shown that some of the older trees date back to pre-colonial days (Buell *et al.* 1954). Bard (1952), who studied succession on the Piedmont of New Jersey, referred to Hutcheson Forest as "the nearest approach to climax" in the area.

The Piedmont of New Jersey is underlain primarily by highly weathered, soft, red Triassic shales of the Brunswick Formation (Lewis and Kummel 1915). The terminal moraine of the Wisconsin glacier crosses the Piedmont a few miles north of the Hutcheson Memorial Forest. Even though the area of the forest is south of the moraine, gravel of origin foreign to the area is scattered throughout. On a few acres at the western end, sand of glacial alluvial origin (Salisbury 1902) overlies the shales.

In early soil surveys, the soils of most of the woods were mapped as the Penn silt loam (Lee and Seltzer 1926). Since the soil is not entirely residual, derived from red shale, but contains gravel brought in from elsewhere it is separated from the Penn and given the name Norton (Quakenbush 1955).

The prevailing influence, however, has been that contributed by the red shale over most of the area. The ferrous aluminum shales were weathered to near completion during sedimentation in Triassic time (Joffe 1937), and this highly weathered condition has inhibited the development of the normal podsolic soil of the region.

The mean annual temperature of the general area, as shown by the records at the weather station eight miles away at New Brunswick, is 53.9° F. Sparkes and Buell (1955), in a microclimatic study in the forest, found the year's extremes to be −3° F. minimum and +96° F. maximum. The temperature range would probably be extended during extremely warm or cold years; the duration of the growing season for the area is approximately 240 days. The annual rainfall is 40.15 inches and July and August receive slightly more than the other months (Biel 1958).

The objectives of this study were to (1) describe the forest, its composition and structure; (2) to discover its relations to other adjacent forests of the region; (3) and to learn the process of recovery from local catastrophe within the forest—an important part of the forest's dynamics.

The author is indebted to Drs. M. F. Buell, H. F. Buell, and J. A. Small for their suggestions during the course of study and for their helpful comments on the manuscript.

METHODS. A detailed tree census was conducted during the winter of 1956–57 in which all individuals over 1 inch d.b.h. were measured. The census was accomplished by dividing the forest into strips of convenient width. Species which were present in the forest only as a few scattered trees, sassafras (*Sassafras albidum*), black cherry (*Prunus serotina*), tree-of-heaven (*Ailanthus altissima*), American hornbeam (*Carpinus caroliniana*), and hackberry (*Celtis occidentalis*) were not included. Nomenclature follows Gray's Manual (Fernald 1950).

Cover data on the shrub and understory layers was obtained by the line intercept method (Buell and Cantlon 1950). A total of five 200m. transect lines were used in both the well-drained and the poorly-drained areas. Forty one-square-meter quadrats were used to sample the herb layer in the well-drained area each season and for the late summer in the poorly drained area. The spring herb cover data of the low areas were obtained from thirty-six one-square-meter plots. Gap closure was studied only by making reconnaissance notes.

RESULTS. Of approximately 65 acres in the Hutcheson Memorial Forest about 82% is situated on well-drained sites while the remainder occupies soil that has poor drainage. For the purposes of this paper, data collected from these two situations are considered separately for both cover and gap closure.

COVER DATA.

Trees.—White oak (*Quercus alba*) is clearly the dominant on both the well-drained and poorly drained areas. On the former, black oak (*Q. velutina*), red oak (*Q. rubra*), and red hickory (*Carya ovalis*) are important associates. White ash (*Fraxinus americana*), red maple (*Acer rubrum*), pin oak (*Q. palustris*), red oak, black gum (*Nyssa sylvatica*), American elm (*Ulmus americana*), and swamp white oak (*Q. bicolor*) are the more important associates of white oak on the poorly drained areas (Table 1). These

TABLE 1. *Trees per acre (Trees/A) and percent basal area (%B.A.) for trees over 1 inch d.b.h. on well-drained and poorly drained sites in the Hutcheson Memorial Forest.*

Species	Well-drained Areas		Poorly Drained Areas	
	Trees/A	% B.A.	Trees/A	% B.A.
Quercus alba	30	52	13	27
Quercus velutina	13	22	3	3
Quercus rubra and *Q. coccinea*	13	12	10	8
Carya ovalis	7	6	6	2
Fraxinus americana	22	3	47	15
Acer rubrum	18	3	62	15
Prunus avium	8	2	1	<1
Acer saccharum	2	<1	<1	<1
Fagus grandifolia	2	<1	2	1
Acer platanoides	2	<1	<1	<1
Ulmus americana	1	<1	10	5
Carya ovata	1	<1	4	1
Nyssa sylvatica	<1	<1	27	6
Quercus palustris	<1	<1	3	10
Quercus bicolor	—	—	2	5

All figures have been rounded to the nearest whole number. The total basal area per acre was 89.5 sq. ft. in well-drained areas, and 74.2 sq. ft. in poorly drained areas.

species together form a canopy in places as much as 95 feet in height. Storms in 1950 and 1956 blew over more than 300 large trees in the forest. The most severe wind damage occurred in a 6-acre portion of one of the poorly drained areas. Studies made after the storm in 1956 showed that the canopy on the upland areas had approximately 7% unoccupied space against 27% in the poorly drained sites (Table 2). This together with the fact that the poorly drained areas had 16.3 square feet basal area per acre less than the well-drained areas is largely the result of the recent wind damage.

The trees of all species are not equally distributed throughout the forest. White oak, black oak, red oak, and red hickory are evenly distributed on the upland portion, but on the poorly drained sites they are spasmodic in occurrence. The other canopy representatives are less evenly distributed even on well-drained sites. White ash and red maple are associated mainly with former windthrows and other disturbances that open the canopy. Canopy individuals of beech (*Fagus grandifolia*), Norway maple (*Acer plata-*

TABLE 2. *Percent cover for species with more than one percent in the shrub layer and understory, on the well-drained and poorly drained areas and data on unoccupied space in the canopy.*

Species	Well-drained Areas	Poorly Drained Areas
	% Cover	% Cover
CANOPY		
Unoccupied Space	7	27
UNDERSTORY		
Cornus florida	84	9
Fraxinus americana	7	1
Acer saccharum	5	—
Acer rubrum	4	27
Viburnum prunifolium	1	—
Celtis occidentalis	1	—
Carpinus caroliniana	—	4
Nyssa sylvatica	—	3
Ulmus americana	—	3
Carya ovalis	—	2
Unoccupied Space	13	52
SHRUB		
Viburnum acerifolium	24	7
Lonicera japonica	7	—
Cornus florida	6	1
Fraxinus americana	2	4
Acer rubrum	1	7
Viburnum dentatum	—	17
Lindera benzoin	—	11
Smilax rotundifolia	—	11
Prunus serotina	—	5
Viburnum prunifolium	—	4
Rhododendron nudiflorum	—	2
Quercus alba	—	2
Ulmus americana	—	1
Rubus allegheniensis	—	1
Sassafras albidum	—	1
Unoccupied Space	61	56

noides), and sugar maple (*Acer saccharum*) are less frequent and their distribution does not appear to be related to windthrows. Aggregations of all reproductive stages of sugar maple and Norway maple are present in the forest around a few seed trees. Scattered individual seedlings and saplings and occasionally small trees of these species are also encountered throughout the upland areas. Isolated individuals of beech occur occasionally but more commonly are in clones. Shagbark hickory (*Carya ovata*) and American elm are usually found in the transition zone between the well-drained and poorly drained areas. Black gum is almost entirely restricted to the poorly drained area fringing a small stream. Sweet cherry (*Prunus avium*) is rarely encountered in the canopy but is represented by frequent individuals with crowns betwen the canopy and understory. It is most abundant in the forest where light is greatest.

The understory on upland areas forms a stratum about 35 feet in height. Flowering dogwood (*Cornus florida*) is the only abundant tree species restricted to this layer, and its importance is clearly illustrated in Table 2.

Basal area data for dogwood are not included in Table 1 since tree census of this species was not done for the entire forest. However, a complete tally of dogwood was made on 26 acres of upland forest. Based on this, dogwood contributes approximately 17% to total basal area on upland sites. This would make dogwood the third most important tree in respect to basal area. However, since dogwood is a small tree, its basal area is even more striking when only individuals between 1 and 9.9 inches d.b.h. are considered. In this size class it contributes 71% to total basal area and 79% to total density.

The understory on the poorly drained areas does not form as distinct a stratum as it does on the well-drained sites. Dogwood, the principal understory tree of the upland forest, is less common in the lowland portion and is absent from the wetter areas. The small amount of dogwood, the sparsity of other tree species with low stature, and the abundance of red maple (Table 2) of various heights result in a less distinct understory on the poorly drained section.

Red maple is the principal contributor to the understory in the poorly drained areas (Table 2). Transgressives of this species, though distributed throughout, are more important on sites with the greatest wind damage. In such sites transgressives of seed origin are less important than those of stump sprouts. Red maple is rarely uprooted but rather broken off near the ground. Numerous sprouts begin to grow. Two or three eventually gain dominance while the others die. In areas of little wind damage, transgressives from stump sprouts are not as important as those from seed origin.

Shrubs.—Maple-leaved viburnum (*Viburnum acerifolium*) is by far the principal species of the shrub layer on upland areas (Table 2). The species forms a distinct layer 3 to 4 feet in height. In windthrow areas Japanese honeysuckle (*Lonicera japonica*) is quite abundant but it is usually suppressed in dense shade. Whenever a windthrow occurs near a honeysuckle vine, its growth rate increases and it begins to climb onto surrounding vegetation. Dogwood transgressives form a conspicuous part of the shrub stratum, particularly in windthrow sites.

The shrub layer of the poorly drained areas differs from the shrub stratum on the drier sites in several respects: (1) more cover, (2) higher, and (3) more species involved. Arrowwood (*Viburnum dentatum*), spicebush (*Lindera benzoin*), and greenbrier (*Smilax rotundifolia*) are the most important. Transgressives of red maple, white ash, American elm, sassafras, and black cherry form an important part of the shrub layer in the vicinity of windthrows. Black haw (*Viburnum prunifolium*) and *Rubus alleghenien-sis* are also associated with windthrows.

Herbs.—On upland areas there are several distinct differences in the herb layer between spring and late summer. (1) Each season is characterized by different species: May-apple (*Podophyllum peltatum*) in the spring and *Circaea quadrisulcata* in late summer. (2) Total unoccupied space is 32% higher in late summer, and (3) *Circaea quadrisulcata* is the only species with an appreciable increase in cover from spring to late summer.

Pokeweed (*Phytolacca americana*) is the most commonly encountered herb with less than 1% cover. In shaded areas, individuals attain a height of a few inches and they never flower and fruit. Whenever a windthrow occurs, pokeweed may reach a height of about 6 feet and produce abundant flowers and fruits.

Two species, spring beauty (*Claytonia virginica*) and rue anemone (*Anemonella thalictroides*), are more important than the data indicate. They appear in early April, and by May 27 (time spring data were collected) they have completed active growth, flowering, and fruiting, and are beginning to die back.

Maximum herb cover on upland areas is reached during May, and May-apple is the principal contributor. Its period of most active development is before the leaves of woody species are fully expanded. By early June the canopy is completely closed, and subsequently herb cover begins to decline.

The spring herb layer on the lowland areas is never as pronounced as that on upland sites. On the poorly drained portions it is dominated by spotted touch-me-not (*Impatiens capensis*) which, at maturity, is about 4 feet in height. It occurs in great quantities along the stream and in those sections of the lowland areas that were not damaged by recent wind storms.

Skunk cabbage (*Symplocarpus foetidus*) is second to spotted touch-me-not in its contribution to ground cover. This species is mainly concentrated in a zone that fringes the stream.

Jack-in-the-pulpit (*Arisaema triphyllum*) and *Circaea quadrisulcata*, both important on the upland sites, are of equal significance on the lowland area. In spring, where windthrows have opened up the forest, the principal plants of the herb layer are Virginia creeper (*Parthenocissus quinquefolia*), poison ivy (*Rhus radicans*), and smartweed (*Polygonum* spp.).

A total of 41 herbaceous species were encountered in the spring sampling but only 37 in late summer.

The moss cover is one of the conspicuous characteristics of the poorly drained areas. This is partially a result of a greater concentration of windthrows which expose mineral soil as well as a tangled mass of fallen trees which become habitats for corticolous and epixylic mosses.

GAP CLOSURE DATA.

Closure of gaps created by windthrow trees follows general patterns that

are largely dependent upon the size of the windthrow. The complexity of the process and the number of species involved in gap closure increases with the size of the windthrow.

In one-tree windthrows on upland sites, the process is simplest. The first stage in gap filling is a burst of growth of the plants that are present. This means an increase in density and height of the shrub layer in the opening. Tree seedlings and saplings already within the area of augmented light (most commonly dogwood and white ash) are the principal candidates to fill the gap, although all tree species participate to some degree. Red maple is also a frequent gap component. It, along with some white ash, seeds in after the gap is formed. The ability of these two species to become established by seeding in windthrow areas as well as sprouting from bases of fallen trees contribute to their aggressiveness in gap closure.

The most conspicuous components of young windthrow sites are pokeweed, *Rubus allegheniensis* and *R. occidentalis*. Pokeweed is an unusually common herb in the woods, but in shaded areas it is present as inconspicuous seedlings a few inches in height. Under the augmented light conditions in windthrow areas, pokeweed grows very rapidly and soon may attain a height of six feet. It reaches its peak of development during the first three to five years of the gap, after which suppression by shading begins to reduce pokeweed importance until it occurs again as inconspicuous seedings.

Rubus allegheniensis and *R. occidentalis* both make their appearance in the windthrow during the earlier years, and during the second and third are conspicuous members of the vegetation. These two species usually increase in importance for 4 to 5 years when adequate shade is present to eliminate them.

Many herbaceous, old field species appear in windthrow openings during the early years either from seeds brought in after the opening was made or from seeds already present in the soil (Oosting and Humphreys 1940). These form a consistent but unimportant group insofar as gap closure is concerned. The number and abundance of this group are dependent upon the size of the gap and the location of the gap in relation to a seed source.

Woody "weed" species common to openings are several, but none of them are important to gap closure. Sassafras, black cherry, tree-of-heaven, smooth sumac (*Rhus glabra*), winged sumac (*R. copallina*), and red cedar (*Juniperus virginiana*) are found in the forest, but their existence there is wholly dependent upon openings.

Gap closure in the canopy is primarily a function of the forest species present rather than the function of woody adventives. The presence of the latter reflects only the changed forest environment which makes their existence possible. It is primarily white ash and red maple with occasional oak or hickory that appear to be the ultimately successful large trees in the openings.

DISCUSSION. Two features of the William L. Hutcheson Memorial Forest reflected in this study stand out as especially interesting. In the first place, being an old forest dating back to the Indian period, it is instructive to compare it with the regional forest vegetation as described by other students. Secondly, since it is located in a region subjected periodically to damaging windstorms, the process of regrowth within storm created openings is an important feature.

Relationship to the regional deciduous forests.—The oak-hickory forest is typical of the southern Piedmont (Oosting 1942). There is a transition from this type of forest to the hemlock-white pine-northern hardwoods described by Nichols (1935) which occurs in western New England (Nichols 1913, Egler 1940), in New York (Bray 1930, Hotchkiss 1932), and in western Pennsylvania (Lutz 1930, Hough 1936, Goodlett 1954). The region between the Piedmont of New Jersey and the area of the hemlock-northern hardwoods dominance is characterized by mountainous or rugged terrain. In this transition zone considerable overlapping occurs between the oaks and hickories and the species of the northern hardwoods, the dominants being determined primarily by the water relations of the site, which are in turn governed by physiography. Niering (1953), working in the Ridge and Valley Province of northwestern New Jersey, mapped by Braun (1950) as the oak-chestnut forest region, found the local physiographic features to have a controlling influence. According to Niering's study, the vegetation is a matrix of chestnut oak with ericaceous shrubs on the xeric uplands, white oak and hickory in the broad valleys, and segregates of the hemlock northern hardwoods in the most mesic sites. Similar situations have been reported in the Palisades of northeastern New Jersey by Collins (1956), in the Jersey Highlands by McDonough and Buell (1956), and in the Watchung Mountains by Baird (1956). A few miles west of the Hutcheson Memorial Forest, Cantlon (1953) reported the oak forest present on the north-facing and south-facing slopes of Cushetunk Mountain, although the northern hardwood members were more important on the north-facing slope.

East of the Piedmont on the Coastal Plain the nature of the vegetation changes rapidly. A large portion of the fire-ridden Coastal Plain of New Jersey is occupied by the Pine Barrens dominated by *Pinus rigida* (McCormick 1955, Andresen 1959). The portions of the Pine Barrens not occupied by pines are dominated by oak (Little and Moore 1949, Buell and Cantlon 1950). On the heavier Coastal Plain sediments of the Delaware River Valley, the vegetation is richer in species and is more diversified.

There is little doubt that the Hutcheson Memorial Forest represents a variant of the oak-hickory forest of the Piedmont. This is borne out by the fact that white oak, black oak, and red oak contribute 43%, 19%, and 10%

respectively to total basal area on upland sites. Red hickory ranks fourth with 5%. The problem that exists is, where in the Piedmont oak-hickory forest complex does Hutcheson Memorial Forest belong. Oosting (1942), in his work on the Piedmont of North Carolina, stated that three climax upland hardwood forest types were recognizable: (1) white oak-black oak-red oak type, (2) white oak-post oak type, and (3) white oak type. To illustrate the similarity in compostion between the white oak-black oak-red type on the Piedmont of North Carolina with Hutcheson Memorial Forest, Table 3

TABLE 3. *Percent basal area for species in the Hutcheson Memorial Forest and in the white oak-black oak-red oak forest type in the Duke Forest, North Carolina* (Oosting 1942).

Species	North Carolina % of Basal Area	New Jersey % of Basal Area
Quercus alba	52	43
Carya spp.	13	5
Quercus rubra and *Q. coccinea*	8	10
Quercus velutina	5	19
Cornus florida	3	17
Nyssa sylvatica	2	< 1
Acer rubrum	< 1	2
Others	17	4

was compiled. The major differences in percent basal area involve a decrease in the importance of hickory, an increase in black oak and dogwood, and the absence of post oak (*Quercus stellata*) in the Hutcheson Forest. These differences may be associated with the effects that the more northerly latitude would have on temperature and moisture.

It is interesting to note that Niering's (1953) study shows that white oak contributes 32% to cover and hickory 15% as compared to 42% and 5% basal area respectively in Hutcheson Memorial Forest.

The above comparisons appear to establish Hutcheson Memorial Forest as a variant of the oak-hickory forest of the Piedmont. A study of size class distribution of tree species indicates that a principal northern hardwood element, sugar maple (*Acer saccharum*), is increasing in importance in the Hutcheson Memorial Forest (Monk 1961). White oak and hickory reproduction is very limited in the Hutcheson Forest. Perhaps this indicates the most significant difference between this forest and that of the southern Piedmont where the oaks and hickories appear to enjoy climax status.

Gap Closure.—As already described, the process of gap closure is essentially one of localized secondary succession. Components important in gap closure fall into three general categories: (1) shade tolerant species whose seedlings are capable of growing or remaining suppressed until a gap is formed; (2) shade intolerant species that are prolific seed producers, whose seedlings cannot withstand suppression for extended periods though present at all times through the replenishment of seedlings from year to

year; and (3) species with wind transported seeds. When a gap is formed the old field species make their initial appearance and there is a burst of growth of the species present in shrub and herb layers. The omnipresent seedlings and saplings of flowering dogwood and white ash along with red maple which rapidly seeds into windthrow areas overtop the shrub layer in 5 to 6 years. Transgressives of the other forest trees are sometimes present. The crowns of the transgressives begin to coalesce, forming a stratum above the shrub layer. As this occurs, the old field shrubs and herbs begin to disappear rapidly. The herb and shrub layers begin to approach their normal appearance in the forest. Sassafras, black cherry, tree-of-heaven, red cedar, and sweet cherry may die through competition in gap closure. This occurs particularly during the interval between the time when the crowns of the young trees have essentially coalesced at 8 to 10 feet and the period when the dogwoods attain their understory height of 20 to 30 feet and are overtopped by the few remaining transgressives. These continue to fill the gap.

An interesting process is recognized when the phenomenon of gap closure is considered from the initial opening to closure. The initial opening of a forest destroys the pronounced stratification by removing the canopy and understory and by disturbing the shrub and herb layers. As the gap begins to close the sequence of re-stablishment progresses from the herb layer to the shrub layer to the understory and canopy.

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Past and present influences on reproduction in the William L. Hutcheson Memorial Forest, New Jersey

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MONK, CARL D. (U. Florida, Gainesville.) Past and present influences on reproduction in the William E. Hutcheson Memorial Forest, New Jersey. Bull. Torrey Bot. Club 88(3): 167–175. 1961.—White oak and black oak collectively contribute 68 per cent to total basal area of canopy tree species; seedlings of these species are fairly common while saplings are rare. On the other hand, sugar maple and Norway maple collectively contribute less than 1 per cent to total basal area, but seedlings of these two maples are common and their saplings are more common than oak saplings. Sapling growth data for the 1956–58 seasons show that sugar maple saplings grew better in the shaded areas of the forest than did other species studied. The pre-colonial fires appear to have favored the oaks but excluded sugar maple. With the cessation of fire after settlement sugar maple seeded in from a nearby source on the flood plain or, as with Norway maple, from shade tree plantings.

The William E. Hutcheson Memorial Forest is a mature oak forest on the Piedmont of New Jersey (40°30′N, 74°34′W). Its history extends back to pre-colonial times (Buell et al. 1954, Buell 1957). The principal disturbance by white man has been the removal of fallen trees and some wind-damaged trees (Monk 1957). Considerable change in the forest has apparently occurred in the last 250 years or so, since protection from fires has permitted many natural changes, and some introduced species have been successful (Adjemovitch 1958). A description of this forest has recently been published (Monk 1961).

The objective of this paper is to examine past and present influences of shade and fire on the reproduction of trees within the forest.

METHODS: A tree census of the forest was made during the winter of 1956–57. With the exception of dogwood (*Cornus florida*), all individuals in the forest stand over 1 in. d.b.h. were measured. This was accomplished by establishing parallel strips 10 to 15 m. wide across the forest. Individuals less than 1 in. d.b.h. were counted in quadrats. A total of 53 20-square-meter quadrats were used to sample saplings (>1 ft. high and <1 in. d.b.h.). One hundred and six 1-square-meter quadrats were used to sample seedlings (<1 foot high).

The nomenclature follows Gray's Manual (Fernald 1950).

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RESULTS

Distribution in size classes.—The census showed that in the larger size classes white oak (*Quercus alba*), black oak (*Q. velutina*), and red oak (*Q. rubra*) are the principal contributors to basal area. Others are red hickory (*Carya ovalis*), white ash (*Fraxinus americana*), red maple (*Acer rubrum*), pin oak (*Q. palustris*), sweet cherry (*Prunus avium*), black gum (*Nyssa sylvatica*), American elm (*Ulmus americana*), swamp white oak (*Q. bicolor*), beech (*Fagus grandifolia*), shagbark hickory (*C. ovata*), sugar maple (*A. saccharum*), Norway maple (*A. platanoides*), and scarlet oak (*Q. coccinea*).

The various species reach maximum numbers in different size classes (Table 1). The species can be placed into two general categories: Group 1,

TABLE 1. *Size class distribution of individuals over 1 in. d.b.h. for trees on upland (U) and lowland (L) sites in Hutcheson Memorial Forest. All trees over 1 in. d.b.h. were measured on 53.5 acres of upland forest and 11.4 acres of lowland forest. These data have been adjusted to a per acre basis.*

Species		TREES PER ACRE IN D.B.H. SIZE CLASSES							
		1–4	5–9	10–14	15–19	20–24	25–29	30	Total
Quercus alba	U	0.8	3.4	8.2	10.3	5.4	1.2	0.3	29.6
	L	1.0	2.8	1.8	3.7	2.8	1.1	0.1	13.3
Quercus velutina	U	0.9	1.9	3.8	3.4	2.3	0.7	0.2	13.2
	L	0.2	0.5	1.8	0.4	—	—	—	2.9
Quercus rubra	U	3.5	3.5	2.4	1.8	1.1	0.4	0.1	12.8
(and *Q. coccinea*)	L	3.2	2.9	1.8	1.1	0.8	0.1	—	9.9
Carya ovalis	U	3.0	0.7	1.2	1.4	0.5	t*	—	6.8
	L	4.7	0.7	0.2	0.2	0.1	—	—	5.9
Fraxinus americana	U	17.5	3.4	0.7	0.2	t	t	—	21.8
	L	30.5	10.7	4.3	1.4	0.5	0.1	—	47.4
Acer rubrum	U	13.7	3.1	0.6	0.1	t	—	—	17.5
	L	44.1	13.7	3.0	1.1	0.1	0.2	0.1	62.3
Prunus avium	U	3.9	4.1	0.2	—	—	—	—	8.2
	L	0.9	0.2	—	—	—	—	—	1.1
Fagus grandifolia	U	1.3	0.3	0.1	0.1	—	—	—	1.8
	L	1.5	0.4	0.1	—	0.1	—	—	2.1
Carya ovata	U	0.4	0.2	0.2	t	t	—	—	0.8
	L	1.6	1.5	0.6	—	—	—	—	3.7
Ulmus americana	U	0.5	0.4	t	t	—	—	—	0.9
	L	6.1	3.0	1.5	0.2	0.2	0.1	—	11.1
Quercus palustris	U	t	0.1	t	t	—	—	—	0.1
	L	1.0	1.6	3.0	0.8	0.5	0.1	0.2	7.2
Acer saccharum	U	1.6	0.1	0.1	—	—	—	—	1.8
	L	0.1	0.1	—	—	—	—	—	0.2
Acer platanoides	U	1.4	0.2	—	—	—	—	—	1.6
	L	0.1	0.2	—	—	—	—	—	0.3
Nyssa sylvatica	U	0.3	0.2	—	—	—	—	—	0.5
	L	16.0	9.6	1.6	0.2	—	—	—	27.4
Quercus bicolor	U	—	—	—	—	—	—	—	—
	L	0.1	0.5	0.4	0.2	0.4	0.1	0.2	1.9
Totals	U	48.8	21.6	17.5	17.3	9.3	2.3	0.6	117.4
	L	111.1	47.8	20.1	9.3	5.5	1.8	0.6	196.2

* t = <0.05 trees/acre

those species represented predominantly by large individuals and, Group 2, those present in greater numbers as small individuals. Pin oak and swamp white oak fit in neither of these categories.

Group 1 includes the white and black oak. It is evident that they are best represented by a size class of 10 to 25 in. d.b.h. There is a general decline in numbers both above 25 in. d.b.h. and below 10 in. d.b.h. A few of the larger trees reach 40 in. d.b.h. Below 10 in. d.b.h. both white oak and black oak are represented by comparatively few trees—7.8 trees per acre collectively or less than 5 percent of all canopy tree species that size. This is in contrast to their contribution of over 40 percent of all trees over 10 in. d.b.h.

Seedling and sapling counts indicate the probable reason for the paucity of small white oaks and black oaks. Black oak seedlings were not encountered in a total of 106 1-square-meter quadrats, and saplings of this species occurred in only one of the 53 20-square-meter quadrats. White oak seedlings were absent on poorly-drained areas and saplings on well-drained areas (table 2).

TABLE 2. *Density (D) and Frequency (F) of seedlings and saplings on well-drained and poorly-drained areas.*

Species	Well-drained Areas				Poorly-Drained Areas			
	Seedlings		Saplings		Seedlings		Saplings	
	D	F	D	F	D	F	D	F
Prunus avium	752	8	5	7	298	30	4	8
Fraxinus americana	301	25	145	77	405	18	321	65
Acer rubrum	267	20	22	20	383	23	76	39
Acer saccharum	117	7	2	3	21	2	—	—
Quercus alba	84	8	—	—	—	—	2	4
Acer platanoides	67	5	2	3	21	2	—	—
Quercus rubra (and *Q. coccinea*)	17	2	2	3	21	2	2	4
Ulmus americana	17	2	5	10	—	—	11	17
Carya ovata	—	—	2	3	—	—	9	13
Quercus palustris	—	—	—	—	85	9	2	4
Carya ovalis	—	—	—	—	—	—	7	13
Nyssa sylvatica	—	—	—	—	—	—	4	8
Quercus velutina	—	—	—	—	—	—	2	4

Group 2 includes the remainder of the tree species. It can be further subdivided into two: (a) species whose successful transgressives are associated with windthrow areas, and (b) species whose successful transgressives are not restricted to windthrow areas.

In group 2a red oak is least closely restricted to open sites. It does not grow in the most shaded areas but is successful in moderatly shaded places. That its seedlings and saplings are more successful than those of white oak and black oak in the forest is illustrated in tables 1 and 2. The red oak

seedling count is less than for white oak, but red oak has approximately 3 times as many individuals between 1 and 10 in. d.b.h. Another interesting aspect of red oak size class distribution is the moderate decline in numbers of individuals from 1 to 25 in. d.b.h.

Successful transgressives of white ash, red maple, red hickory, sweet cherry, shagbark hickory, and black gum are almost entirely associated with the forest margin, windthrow areas, or the edge of the stream. Seedlings of shagbark hickory, red hickory, and black gum are rare in shaded areas, whereas white ash, red maple, and sweet cherry seedlings are abundant (table 2). The cherry seedlings in shaded areas rarely attain a height of one foot.

Saplings of white ash and red maple are abundant in shaded sites as well as in well-lighted areas. Individuals of these species located in shaded areas grow well and appear healthy until they are 5 to 6 ft. in height. Continued suppression by shade results in the death of the saplings.

In group 2b, species with successful transgressives in shaded areas, there are only sugar maple, Norway maple, and beech. Seedlings and saplings of beech of seed origin were not found. This species is presently maintained through root sprouts. Such reproduction of beech is quite successful in shaded areas. Sugar maple and Norway maple, though represented by only 2.0 and 1.9 trees per acre respectively over 1 in. d.b.h., are represented by a fair number of seedlings and saplings. The transgressives of sugar maple and Norway maple are largely localized around the few seed trees, though they are not restricted there.

Sapling Growth.—Height growth of saplings of seven species was measured during the 1956–58 growing seasons. This was done by placing an India ink mark on the terminal leader a few cm. below the terminal bud (Kienholz 1941). The distance from the ink mark to the end of the shoot was measured weekly. When possible, saplings of each species for study were selected in windthrow sites and shaded areas. To determine the relative amount of light received by each sapling, light readings were taken with a Weston photometer during the noon hour in late June. The light intensity in an adjoining field was 10,000 f.c. before and after the readings in the forest. To estimate the percentage of light around each sapling, ten readings were taken in the vicinity of each plant. These were added and averaged and expressed in percent of the 10,000 f.c. It was realized that the light intensity around each sapling may change during the day with changes in the position of the sun; however, the relative light intensities were the primary concern.

The sapling growth data are summarized in table 3. It is of interest to note that of the saplings located in shaded areas (white ash, sugar maple,

TABLE 3. *Sapling height growth for the 1956–58 growing seasons.*

Species	Average Growth in mm. for 1956–58	Percent Light Intensity Around Saplings	Number of Saplings Involved
Acer saccharum	151	1–6	4
	375	15–40	3
Fraxinus americana	86	1–6	5
	442	75	2
Acer rubrum	78	5–15	3
	242	35	4
Carya ovata	48	5	1
	240	35	2
Quercus velutina	443	20	1
Quercus rubra	234	30	1
Carya ovalis	124	15	1
	352	35	1
Acer platanoides	355	30	1

red maple, red hickory, and shagbark hickory) sugar maple grew considerably more than any of the others during the three year period.

DISCUSSION: Bard (1952), in considering the Hutcheson Memorial Forest, stated that many of the larger oak trees live 200 years or more and that mortality of these large trees is low, thus requiring only a few seedlings for replacement. In conclusion, she stated that "the consideration of Mettler's Woods [Hutcheson Memorial Forest] as representing a climax community may be warranted". However, evidence obtained from the present detailed stem count of all size classes seems to indicate a general decline in the importance of the oaks, particularly white oak and black oak, and an increase in sugar maple.

A similar situation has been reported by Braun (1936, 1958) in the mature oak forests on the Illinoian till plain in Ohio. There white oaks with diameters of 3 to 4 ft. are not reproducing themselves, but beech is reproducing.

The most convincing evidence for an increase in sugar maple and possibly Norway maple is the relationship between number of seed trees and transgressives. There are about 6 trees of each of these species that are producing seeds. Transgressives are more numerous in the vicinity of these seed trees, but are not confined to such sites. Both of these maples have about 2 individuals per acre between 1 and 5 in. d.b.h. This is more than for the oaks of the same size class. Oak saplings are fewer than the maples while seedling count is about the same, thus indicating that seedling and sapling mortality is less than for the oaks. It is apparent that the sugar and Norway maples are recent additions to the forest since they are still of minor importance. None have reached the 15 in. d.b.h. size class even

though both show a high reproductive potential.

The cause of the recent introduction of sugar maple and Norway maple is a matter of conjecture. It may be the result of (1) change in climate, (2) changes resulting from the cessation of fires, or (3) a combination of these. There is no evidence in the long-term Weather Bureau climatological data for New Jersey (100 years of data) that indicates that climate has changed enough to explain satisfactorily such a change in vegetation, although over a longer period of time there may have been a change to more mesic conditions in the northeast (Raup 1937).

The most likely environmental change that could have induced the vegetational change is the cessation of fires. There are reasons to suspect that this has played a major role in the development of the woods since colonial times.

That pre-colonial fires were widespread in the northeastern deciduous forest has been well documented (Day 1953). Day refers to numerous papers which give a general description of the pre-colonial and colonial forests along the eastern coast. The terms "stately oaks" and "park-like" often appeared in the descriptions, and frequent mention was made of the sparse undergrowth which favored travel through the forests. Humphrey (1931) quotes similar descriptions. If these descriptions are valid, the character of the forests has changed considerably since colonial days. The high percentage of shrub cover today certainly does not give the forest a park-like appearance, and traveling on horseback through the woods would be difficult.

Trees differ in their resistance to fire. In parts of the country this is being capitalized upon by foresters through a prescribed burning program in an attempt to produce or maintain a forest in a subclimax state that may be more valuable economically than the climax vegetation. Garren (1943), in his review of fire in the southeastern conifer forest, points out numerous species that increase with repeated fire and decrease with cessation of fire. The effects of fire in maintaining pine as the dominant tree in the Pine Barrens of New Jersey has been shown by Little and Moore (1949). Buell and Cantlon (1953) reported a great reduction in shrub cover with frequent prescribed burns in the pine region of New Jersey. The reduction in shrub cover would tend to convert the appearance of the forest to park-like, as mentioned in early descriptions of the eastern deciduous forest.

There is considerable agreement that protection from fires favors sugar maple. Daubenmire (1936), in his study of the "Big Woods" of Minnesota, stated: "the behavior of sugar maple, the most fire sensitive species, at the western edge of the Big Woods is particularly noteworthy. It is completely absent in those places where fire barriers are so ineffective that

they have served only to lessen the intensity of burning. In such places a gradual transition occurs from pure maple-basswood forest to bur oak savanna, and it is always the sugar maple which is the first to drop out."

Cottam (1949) found that the bur oak savanna of southwestern Wisconsin could be transformed to dense woods in 100 years. Cottam considered that the "cessation of these fires at the time of settlement enabled the oak openings to grow into oak woods, and unless further catastrophes interfere, the woods seem destined to become a climax Acer-Tilia woods."

In a comparison of surveyors' records with present day forest composition in Wisconsin, Ward (1956) found that there has been a great increase in the importance of sugar maple. Evidence is given by him which suggests that fire does eliminate sugar maple except in protected sites. In mesic forests in Wisconsin, Eggler (1938) found that "under conditions following immediately after severe burning oaks would be more successful in reproduction than maples." That oaks are more fire resistant than sugar maple was pointed out also by Starker (1934). Dix (1957) studied the vegetation in the National Zoological Park, Washington, D. C., which had been protected under the National Park Service for the past 67 years, and found sugar maple to be the principal understory species. Dix attributes this increase in sugar maple to protection from grazing and fire, and to the removal of the chestnut.

Bromley (1935) thought the extensive oak-chestnut-hickory-pine forest type of southern New England may have been due to frequent fires. He considered that this forest type was yielding to the white pine-hemlock climax in which sugar maple would be an important member.

Raup (1937) recognized a southward shift of the ecotone between the northern and southern hardwood forests of New England. He felt that the "fires helped to maintain it [pre-colonial oak-chestnut-hickory type] against the competition of the more mesophytic forests to the northwest, but that fires were the sole factor in maintaining it is difficult to believe." He attributed the apparent change to a cooler and more moist trend in the climate within the past 3000 years.

From the above references it is apparent that a recent increase in sugar maple is not restricted to the Hutcheson Memorial Forest. It is apparent that these areas of increase are situated on the periphery of the main distribution of sugar maple. Perhaps, in all these, sugar maple was restricted by fire until 100 or 200 years ago.

It has already been shown that the Hutcheson Memorial Forest has had a past history of fire. Buell et al. (1954) found that the forest was burned at approximately 10-year intervals, before and during early colonial days. The date of the last fire recorded was in 1711. This report is significant in that it shows that fires of sufficient intensity to scar tree bases occurred

only before or in the first years of colonization.

Below the canopy of the pre-colonial forest the subordinate vegetation was evidently much less dense than that at present. Hence, the greater amount of light would have created more favorable conditions for survival of young oaks.

The present size class distribution of the oaks, concentrated around 15 in. d.b.h., suggests that conditions were more favorable for them earlier. Annual ring counts of ten windthrown oaks revealed that trees of this size class are between 200 and 225 years of age. The open conditions created by the frequent pre-colonial fires were probably still existing some years after the last recorded fire in 1711 when many of the present oaks got started. With the cessation of fire and the subsequent increase in the density of the vegetation, the ability of the oaks to maintain their high level of dominance began to decline. Today the oaks are still dominant and will remain so for a long time. However, the low survival rate of transgressive oaks and the successful introduction of the shade tolerant maples suggest a trend toward a forest with more maple.

The Norway maple, of course, is an introduction from Europe. It is a favorite shade tree in central New Jersey and, hence, there has been an abundant seed source. Although Dansereau (1957) reports it to be generally unsuccessful in North America, in Hutcheson Memorial Forest it equals sugar maple as an aggressive species. The sugar maple in the forest may also have had shade plantings as a seed source although it does occur naturally on the local flood plains (Buell and Wistendahl 1955).

That the difference in success of certain of the tree species in the Hutcheson Memorial Forest is related to their different responses to low light intensities is suggested by data in Table 3. Sugar maple shows the best growth at low light intensities of all species tested. This ability of sugar maple to grow in low light intensities is supported by the work of Burns (1923).

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TORREYA

Drought Effect on Radial Growth of Trees in the William L. Hutcheson Memorial Forest

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Radial changes in tree trunks based on dendrometer measurements have been given considerable attention. However, the studies have taken various approaches and have employed a variety of methods. Considerable interest has centered around growth rates, annual increments, dates of growth inception and cessation, and attempts to relate these to temperature, moisture and sometimes photoperiod and phenological data. In some cases work has been limited either to intensive study of one species in one habitat or to comparisons of one species occurring in various habitats (Friesner 1941, Friesner and Walden 1946, Byram and Doolittle 1950, Daubenmire 1950, Fritts 1956 and 1958). Other studies involved a number of species, usually showing up a variety of responses of the different species in the same environment or contrasting responses in different environments (Ahlgren 1957, Cantlon 1953, Daubenmire 1946, Daubenmire and Deters, 1947, Eggler 1955, Fowells 1941, Friesner 1942, Jackson 1952, Reimer 1959). Radial growth studies have been used in forestry research where radial changes have been related to forest thinning and pruning experiments (Brown, Rose, and Spurr 1947, Stevens and Spurr 1947). Some of the radial stem changes observed in studies with the dendrometer have been somewhat clarified through the use of concurrent histological studies (Fraser 1952 and 1956, Monk 1959a) which have shown that, in the early spring, initial enlargement is the result of swelling of tissues, followed later by cambial activity. These and other studies of radial growth using dendrometers have been undertaken as specific problems of stem growth.

In 1950 dendrometer measurements were initiated not in an effort to solve any specific problems but as one of a number of types of observations on growth and periodicity in the oak forest of central New Jersey. These measurements have served to document growth phenomena of a variety of broadleaf tree species characteristic of this area. One of the most striking results of the study so far is the influence of the severe summer drought of 1957 on the radial changes of the species involved. The presentation of that phenomenon is the objective of this paper.

The trees used in the study were all located in the William L. Hutcheson Memorial Forest which is on the Piedmont Plain of central New Jersey. The topography is gently rolling. In part it is well-drained and in part the drainage is poor, having a pattern that is especially well shown by the shrub distribution (Monk 1957). The soil, derived primarily from the Triassic red shale of the Brunswick formation is comparatively shallow. The forest consists principally of white, black and red oaks (Buell 1957, Monk 1959b).

Methods. The dial gauge dendrometer as described by Daubenmire (1945) was used. Screws were set at about 4 feet from the ground on the north and the east sides of the trees. Readings were taken at weekly intervals and in the early part of the morning.

Twelve species of trees were being measured in 1957. At last two trees of each species were included and in every case where possible one of the pair occurred on low ground and one on well-drained land. Those included were: *Acer platanoides, A. rubrum, A. saccharum, Carya ovalis, Fagus grandifolia, Fraxinus americana, Quercus alba, Q. rubra* (on upland and lowland); *Nyssa sylvatica* (on lowland only); *Prunus avium, Q. coccinea,* and *Q. velutina* (on upland only).

Certain of the species reacted to the screws either by developing vertical cracks above and below the screws or by excess cambial growth in their immediate vicinity. Such effects were primarily evident on *Acer platanoides* and *Acer rubrum. Prunus avium* produced a gummy exudate at the location of the screws. Regardless of how such responses may effect

growth, drought effects on these species were parallel with the effects on other species.

Nomenclature follows that of Grays Manual, 8th ed. (Fernald 1950).

Results. Typical growth curves of the trees show a period of fluctuation during the winter and early spring (fig. 1), followed by a more or less consistent increase in radius

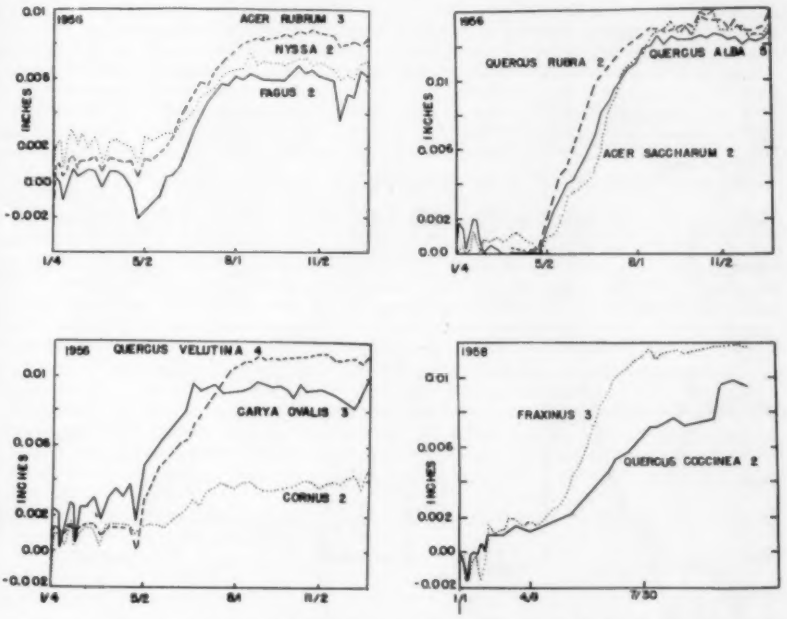

FIG. 1. Growth curves of individual trees of several species during years of normal rainfall. Numbers after species names are individual tree identifications in the growth studies in the forest. Weekly readings are plotted to produce the curves.

until about mid-summer after which there is only a gradual increase until fall, or sometimes no increase. Late summer and fall are marked by moderate radial fluctuations. By late fall the trees are commonly slightly less than the maximum previously attained, a phenomenon noticed by Byram and Doolittle (1950). The winter is a period of fluctuating tree size. The point where consistent radial expansion starts in the spring varies with the species, and the species vary from year to year. Because of the fluctuations of the curves during the winter and spring, it is especially difficult to determine for certain a starting date for annual radial increment. Actually for the purposes of this paper it is not essential to do so. It will appear from inspection of figure 2 that as a result of the drought the contraction of the stem in some species equalled or even exceeded the starting point of growth in the spring as for example *Carya ovalis*.

The summer of 1957 was one of extreme drought for this climate (Table 1). The growth curves for all species in that year are quite different from all other years (fig. 2).

TABLE 1. *Precipitation Records of the Weather Bureau Station at New Brunswick, N. J., 8 Miles East of the Study Area.*

	1950	1951	1952	1953	1954	1955	1956	1957	1958	Mean for the 9 yr. period
January	2.37	3.02	4.81	5.31	1.91	0.71	2.22	2.02	5.46	
February	3.82	4.16	2.18	2.26	1.88	2.52	5.09	2.51	4.10	
March	3.53	4.75	3.82	7.84	3.54	4.86	3.31	2.98	4.53	
April	2.19	3.21	5.84	5.46	3.64	2.45	3.23	5.66	5.97	
May	2.87	4.02	5.87	4.64	3.67	1.84	2.84	0.96	4.09	3.42
June	2.28	3.62	4.65	3.25	1.64	2.63	3.15	2.19	2.99	2.93
July	6.78	4.26	4.90	2.96	1.11	1.43	3.93	1.31	5.86	3.61
Total for May, June, July	11.93	11.90	15.42	10.85	6.42	5.90	9.92	4.46	12.94	9.97
August	4.57	2.98	7.35	2.86	7.74	13.77	4.67	3.66	3.27	
September	1.76	0.87	3.36	1.09	5.66	1.83	3.19	2.32	3.28	
October	1.42	4.99	0.63	3.88	2.83	6.80	3.50	2.03	6.26	
November	5.10	—	3.58	1.98	5.46	2.21	4.33	3.92	2.33	
December	3.42	6.67	2.74	4.24	3.32	0.17	4.12	5.71	1.67	
Annual	40.11	—	49.73	45.77	42.40	41.04	43.58	35.27	49.81	

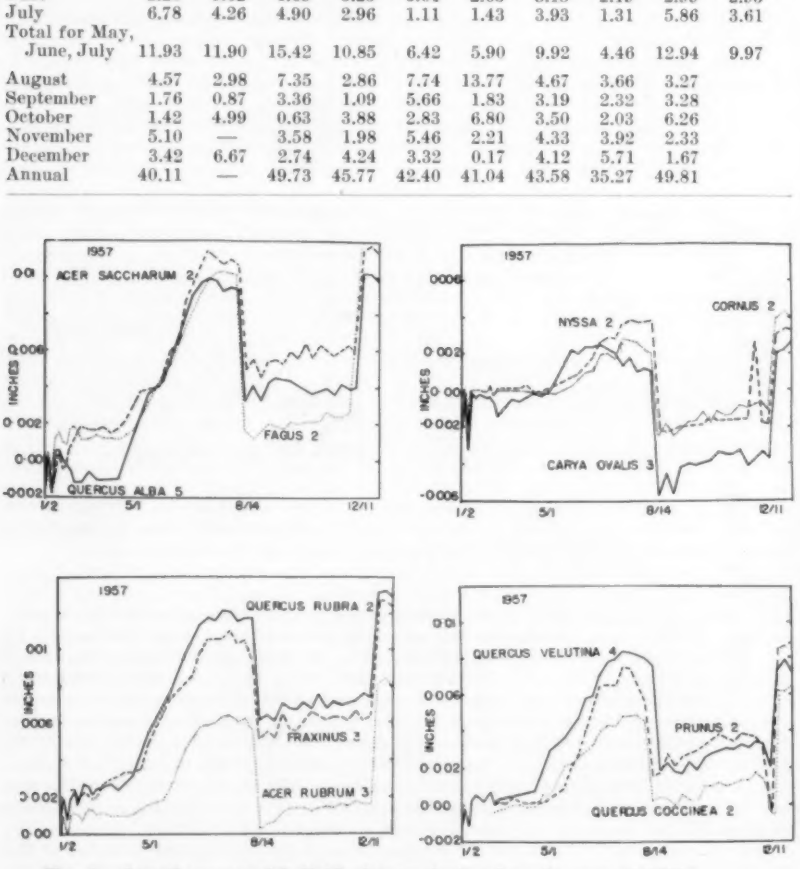

FIG. 2. Growth curves of individual trees during drought year of 1957.

The radial increment in the spring followed the usual course but the growth curves had leveled off and started to decline by mid-July. On August 7 an abrupt radial decrease of astounding magnitude occurred. The readings were taken in early morning as usual, but it takes about an hour to make the readings on all of the trees. Before the hour was up, a strong hot, dry wind began to blow through the tops of the trees. The last few trees to be read showed such a pronounced drop from the reading of the preceding week that one of the trees visited before the breeze came up was reread, and it had decreased since the earlier reading that morning. The growth curves in figure 2 are plotted from data collected by the initial reading on August 7. *Quercus coccinea* 2 and *Prunus* 2 were among the last which were read and hence show the precipitous shrinkage recorded on August 7. It first appears as the August 14 reading in the others plotted in the figure. What is especially interesting is that, following this, weekly readings were consistently low until mid-December. On December 18 the trees had returned to their previous maximum, and most of them to a size even larger than they had been before. The size attained by December 18 was maintained. In the 10 years of record, 1957 is the only year that has shown this phenomenon of pronounced shrinkage.

Discussion—The period of rapid radial expansion in spring and early summer, commonly referred to as the grand period of growth, is of especial concern in this study. It usually extends through most of May, June, and part or all of July. Since late summer moisture conditions are usually favorable for plant growth (Table 1), slowing up of growth at the end of this period may sometimes be related to photoperiod as Eggler (1955) has suggested for trees in Lousiana or to a change in the balance between growth regulators (Phillips and Wareing 1958). It is also likely that a change in water balance can often influence the termination of the grand period of growth. It certainly seems to have been the major contributing factor during the summer of 1957 when the development of an extremely unfavorable water balance resulted first in a cessation of growth, next a slight decrease in radius, and finally an abrupt and pronounced reduction in size. The remarkable recovery of the trees in December of 1957 following the drought is probably related to the complete return of normal moisture relations.

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Drought Response in William L. Hutcheson Memorial Forest, 1957

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When many trees, of many species, showed brown and dry leaves on some or all of their branches by September 1, 1957 in Hutcheson Forest, it seemed an opportune time to record the effect of droughtiness on individuals, species, and on the forest as a whole.

The forest is controlled by a grid system providing sections of 100 meters on each side. A reconnaisance was made, trees were noted, the d.b.h. and the location of those trees with apparent top injury was recorded, in September-October 1957. In 1958 the reconnaisance was repeated between July 31 and September 5. At this time an estimate of the degree of injury (leafless branches) was attempted. It appeared possible to separate this injury from dead branches of earlier years. The purpose of the second survey was to: 1. determine the possibility of relocating the trees, 2. increase the accuracy of the data since the 1957 survey ran into autumn coloration as a confusing factor, 3. check upon the possibility that the trees might have escaped into early dormancy and survived, at least to some extent, the drought effects, and 4. ascertain, on the other hand, if drought injury had occurred in 1957 which was not expressed or at least not recognized in the appearance of the foliage at the time of that reconnaisance. Some further checking was done in August of 1959. An attempt was made to assemble any pertinent records of the environment of the forest during 1957 and to make pertinent comparisons.

1. All but two of the trees were relocated, out of a total of 188.

2. As was expected, the number of trees injured or killed proved to be greater when checked in 1958 than was recorded in 1957, but the increase was even more than expected. It also appeared that in some instances the injury had not been as serious as it appeared in 1957. Subsequent observation has corroborated this in some cases, but in others the apparent recovery or survival was a failure. For instance, the largest *Q. alba* in the forest (location 195 × 290) was recorded as killed in 1957. All of its leaves were brown and

appeared dried on the tree. In 1958, however, it put out leafy shoots along the trunk and most of the branches. This was very gratifying, but also misleading because there have been no leaves in 1959 or 1960, and a fairly large branch has already broken off.

3. The question of dormancy was not resolved. It appeared that in some cases buds had been far enough developed to survive and the tree had not suffered otherwise to the extent that the buds failed to function normally in 1958. For instance, on section A8 a 22.4" *Acer rubrum* was noted October 13, 1957 as "apparently done for"; but on September 5, 1958, "top has 40% of expected foliage" and in 1959, "recuperating". On section B8, October 13, 1957, "10.0" *A. rubrum* is drought killed". In 1958 it was found that "top 25% is O.K.". And in 1959 "recovery goes on". On section C2 a 2.2" *Fagus grandifolia* had prematurely brown leaves and appeared dead on October 13, 1957, but in 1958 it had "small leaves on every branch, but they are few". In 1959 it was estimated to have 30% normal leaf crop though some twigs were bare and indeed whole branches on the north side. On section D2 a 5.4" *Cornus* was noted October 9, 1957, "has leaves brown. Dead?" But on June 27, 1958 this was reconsidered as "the *Cornus* appears to have been alive and well. It is in full leaf . . .". In other instances it appears that the normally set buds did not survive to function in 1958 or that some other factor prohibited their function, as witness the 74 trees now dead, and the many trees with dead branches. In addition there is the situation of adventitious buds becoming active though normally set buds failed, as on the big white oak.

4. There was more actual drought injury, as recorded in 1958, than was apparent in 1957. The confusion of autumn coloration no doubt accounted for part of the difference, but it also appears that permanent damage had occurred in trees where the leaves did not get noticeably brown. The number of branches without leaves in 1958 was very much larger than appeared likely in 1957.

The distribution of injured and killed trees through the forest is indicated by sections on the map Fig. 1, adapted from Monk (1956). The distribution of injured and killed trees by species is indicated in Table 1. These figures must be interpreted with little comparative significance since the species that occur in greater abundance show higher numbers in the table, but this certainly does not represent a ratio of occurance or of injury. The New Brunswick station in the state network for precipitation records is located east of the forest at approximately eight miles distance. Data for this station with the long term mean, are presented in Table 2. Soil moisture and wilting point records for the Forest in 1957 constitute Table 3 (Balloni 1957).

Summer droughtiness to some degree is usual in Central New Jersey and irrigation of hoed crops is a commonly accepted practice. Droughtiness has been observed in Hutcheson Forest during several seasons of the past decade. It has been manifested by wilting and drying (brittle) of the leaves of *Viburnum acerifolium* and of *Cornus florida*, particularly at the forest edge. During one season the drought was severe enough so that the *V. acerifolium* in one area frequently showed all leaves dried, brittle, and soon brown. No quantitative data were taken, but selected plants were kept under observation. It was found that the tops died, but the root system did not die because new shoots appeared the next season and persisted.

Summer droughtiness was to be expected in 1957. During the winter and spring U. S. Dept. of Commerce, Weather Bureau records show only April had precipitation at or above normal, May produced only 24.06% of the expected rainfall, June 57.18%, and July 30.82%. The drought effect of reduced precipitation is probably greater than the percentages imply because interception at the various levels in the Forest remained the same, likewise reevaporation, so that the amount reaching the level of root systems in the soil must have been very small indeed. By mid-July, wilting, yellowing, brittleness of leaves could be found. It was noticed that *Lindera* showed more response than usual, more in fact than *Viburnum acerifolium*. In other words, the prolonged water deficit was making itself felt more noticeably in the normally (at least seasonably) wetter parts of the forest, see *Q. palustris*, Table 1. Soil samples from the A horizon in the forest on

July 3 (Institute of Field Biology, class data) ranged from 17.2% to 28.5% moisture on dry weight basis with the average 21.54%. A replicated series averaged 19.9%. On July 11 another sampling showed 16.4% moisture. See Table 3 for further data. Balloni (1957) noticed that the increased moisture in the A_0 layer in mid-September was not accompanied by an equally large increase below. Buell, Buell, Small and Monk (1960) found the trees unable to recover until December.

It is realized that trees die from causes other than drought, even in dry years, but there has never been a year in the more than a decade of continuous observation when so many trees died as in 1957, except the hurricane damage of 1950, 1954, and 1955. Another factor should be recorded, however, in this regard. The Forest is generally infested with the root-rot fungus, *Armillaria mellea*. 1956 was a particularly favorable year for the fungus, as indicated by mushroom production. While it is possible to observe leafless branches in the tree tops, it is not possible to record the degree of root system injury as a result of drought, fungus, or both. It seems reasonable to suppose that such injury occurred and that this contributed to the increased evidence of injury that was observed in 1958.

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TABLE 1. *Tree species damaged and killed, Hutcheson Forest 1957 and 1958.*

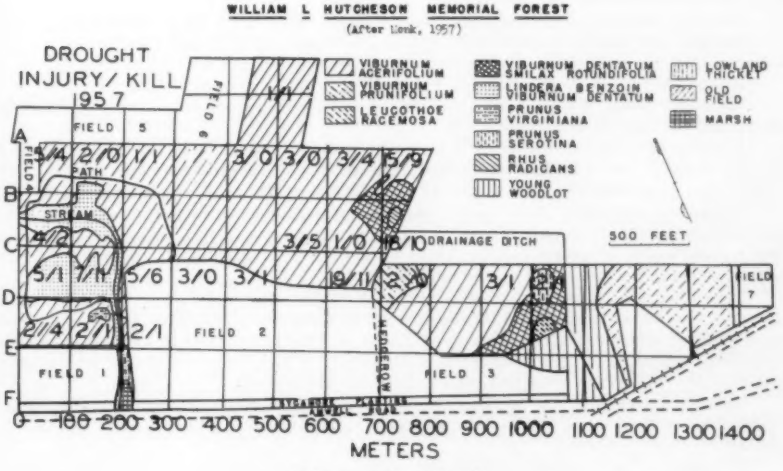
Species		Number Damaged	Number Killed
A. rubrum	Red maple	22	10
A. saccharum	Sugar maple	2	0
Carya ovalis	Red hickory	0	1
C. ovata	Shagbark hickory	0	2
Cornus florida	Dogwood	14	24
Fagus americana	Beech	3	0
Fraxinus americana	White ash	1	2
Nyssa sylvatica	Black gum	2	0
Carpinus caroliniana	Blue beech	1	0
Prunus sp.	Cherry	5	3
P. avium	Sweet cherry	10	0
P. serotina	Sour cherry	1	2
Q. sp.	Oak	1	2
Q. alba	White oak	12	10
Q. bicolor	Swamp white oak	3	1
Q. coccinea	Scarlet oak	2	1
Q. palustris	Pin oak	10	7
Q. rubra	Red oak	7	1
Q. velutina	Black oak	17	4
Ulmus americana	American elm	1	4

TABLE 2. *Monthly precipitation in inches, 1956–1958, and long term mean (1931–1955), New Brunswick, N. J.*

	Jan	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1956	2.22	5.09	3.31	3.23	2.84	3.15	3.93	4.67	3.19	3.50	4.33	4.12	43.58
1957	2.02	2.51	2.98	5.66	0.96	2.19	1.31	3.66	2.32	2.03	3.92	5.71	35.27
1958	5.46	4.10	4.53	5.97	4.09	2.99	5.86	3.27	3.28	6.26	2.33	1.67	49.81
Mean	3.38	2.60	3.86	3.34	3.99	3.83	4.25	4.78	4.19	3.12	3.63	3.06	44.03

TABLE 3. *Soil moisture content at various depths in upland forest on dates given, 1957 (Balloni, 1957)*

Depth	July 30	August 4	August 17	August 31	September 14	September 27	Wilting Point
ao	22%	54%	33.6%	26%	83%	75%	—
0	22	54	33.6	26	83	75	9.6
3	9.6	28	12.5	12	16.3	1.5	9.6
6	8.1	8.3	11.3	11.7	15.6	12.0	7.7
9	7.1	7.8	9.3	10.2	14.2	10.5	7.6
12	6.1	7.9	8.6	9.2	11.3	10.0	7.4
15	6.7	8.1	8.1	8.1	8.6	11.0	8.6
18	8.6	9.2	10.2	8.7	11.5	13.4	9.6
21	8.9	12.0	10.7	8.4	12.5	14.2	10.9
24	9.7	12.3	11.3	8.7	11.4	12.8	10.1
27	9.3	10.8	10.3	12.4	10.4	10.7	8.5
30	8.2	13.0	9.3	10.0	9.3	5.6	7.2
33	8.5	13.8	8.3	7.5	8.1	8.0	8.1
36	9.1	14.4	8.4	7.1	8.1	10.0	8.7



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BOOK REVIEWS

Plant Physiology, A treatise. F. C. Steward, Ed. Vol. 1A. Cellular Organization & Respiration. Vol. 1B. Photosynthesis & Chemosynthesis. Academic Press, New York, 1960.

The need for an authoritative advanced text in plant physiology has become increasingly pressing. Prospecti for symposia and monographs tempt us daily, papers pour out from burgeoning journals, and, for those who are both patient and prosperous, there is a half-finished encyclopedia in the best and worst teutonic traditions. Plant physiology is clearly alive and prospering.

All the more reason for a bastion of theory, agreed fact, and sapient interpretation on which the teacher may found his course, the student seek refuge, or the investigator brave the torrents of new reports and speculations with something approaching composure, discrimination, and even prescience.

We now have three volumes of Professor Steward's treatise, enough to indicate, perhaps, whether this is the text we have been awaiting. The present two volumes consist of five chapters or articles:

Volume 1A

The plant cell and its inclusion, by R. Brown.

Proteins, enzymes, and the mechanism of enzyme action, by Birgit Vennesland.

Cellular respiration, by David R. Goddard & Walter D. Bonner.

Volume 1B

Energy Storage: Photosynthesis, by Hans Gaffron.

Chemosynthesis: The energy relations of chemoautotrophic organisms, by Martin Gibbs and Jerome A. Schiff.

The several chapters are written on quite different levels. Cellular Respiration and Energy Storage are detailed treatments with much for the specialist to wrestle; the former is a particularly lucid account of the theoretical basis of respiration and of the cytochromes in particular. Due in part to his preoccupation with the many pitfalls in photosynthesis, Dr. Gaffron's chapter is perhaps unnecessarily difficult. Chemosynthesis and Goddard and Bonner's chapter serve as models of organization and style for an advanced text: logical, explicit, and economical.

The other two chapters appear intended for quite different readers. Dr. Brown's and Dr. Vennesland's chapters are well-written, but superficial descriptions of very wide fields of study and might have been found in elementary texts in cytology and biochemistry, respectively. It is refreshing, nonetheless, to find a general article on proteins and enzymes with many examples drawn from the plant world.

These volumes thus suffer from inconsistency in general organization. More seriously, they suffer in the details of organization: redundancy, lack of cross references, and an inadequate index.

Throughout both volumes, important areas are dealt with in two or more places on different levels. For example, Dr. Brown for 10 pages (pp. 102–11, Vol. 1A) considers elementary aspects of metabolism, most of which are developed in greater detail by Goddard and Bonner in the same volume. Later Goddard and Bonner give two pages (pp. 275–277) to intracellular localization of enzymes, a topic already developed in detail by Brown (pp. 111–121). Nine pages are allotted by Brown to the physical and chemical composition of chloroplasts (pp. 90–98, 1A), including one electron micrograph. Gaffron gives us 15 pages of similar material (1B, 29–45) including one almost identical electron micrograph. Gibbs & Schiff allude to stored "reducing power" (pp. 309–310), already considered by Gaffron (pp. 149–153) under "pre-illumination". *None* of these citations are cross-referenced and many are not found in the index.

Professor Steward defends plural authorship by declaring that ". . . such a synthesis of current knowledge requires the knowledge and mature experience of many authors . . .". But to achieve that unity and lucidity which characterize a really great treatise—such as Glasstone's *Physical Chemistry*—a far more active editorial role is required than can be detected in these volumes.

There are inevitably a few errors and omissions:

Vol. 1A

p. 113 Centrifugation of breis at 6000 g will sediment a substantial fraction of mitochondria as well as chloroplasts.

p. 120 The matrix (non-particulate cytoplasm) does *not* necessarily "carry all of the glycolytic enzymes".

p. 167 The "complications" attributed to the role of metals in metalloenzymes have turned out to be incorrect.

p. 176 A chelating agent, such as diethyldithiocarbamate, which may be specific in giving a colored complex with only one metal ion in aqueous solution under defined conditions, may or *may not* specifically chelate with that same metal when the metal is already chelated to a protein.

p. 218 No mention is made of the method of Pardee, which allows measurement of oxygen exchange at constant CO_2 tension.

p. 245 Table XI legend has several errors.

p. 251 No reference is made to the several studies of fatty acid oxidation by plant mitochondria. There appears also to be absolutely no reference to the glyoxalate pathway, although this has been recognized for three years as a central phase in the metabolism of organic and fatty acids.

p. 255 In the Nernst equation, R is given in the units of joules·degree^{-1}·mole^{-1}, and the faraday is reported in coulomb·mole^{-1}. With these units, the second term of equation (89) will *not* reduce to volts.

Vol. 1B

p. 149 Six-carbon intermediate *has* been identified (Moses and Calvin, 1958). Also, there is a curious omission of very short-term $C^{14}O_2$ fixation with leaves which show carboxyl-labelled PGA substantially greater than 74%. Reference should also be made to Table IV, p. 313 of the same volume.

While the serious student will want to search these volumes closely, they do not seem to represent the kind of comprehensive text, we have been awaiting.—C. A. PRICE

The Cell. By Carl P. Swanson. 114 pages, 60 text figures. Prentice-Hall Foundations of Modern Biology Series. 1960. $1.50.

This small book is a short treatise on cytology embracing some of the outstanding advances in its various aspects and serves the need of a good reference at the intermediate level. It presupposes an elementary knowledge of biology and chemistry since little space is devoted to explanations of an elementary nature. The organization of the nine chapters is along conventional lines but in my opinion superior to similar treatments in some current textbooks of biology. The subject matter of each succeeding chapter follows in a logical sequence and the information is cumulative as one progresses. It is illustrated with clear simple drawings, some choice photomicrographs and a few diagrams. There is little room for criticism of such a brief and compact treatment of the cell. The book should be in the hands of every biology teacher, especially high school teachers.—S. FLOWERS

The Plant Kingdom. By Harold C. Bold. i–xiii, 1–114 pp. Illus. Prentice-Hall, Inc., Englewood Cliffs, N. J. 1960. Paper bound, $1.50. Cloth bound, $2.95.

Prentice-Hall's FOUNDATIONS OF MODERN BIOLOGY SERIES is designed to "permit each teacher of biology to determine the level and the structure of his own course" by selecting his own combination of volumes from the series. Each book concerns one of the central areas of modern biology and is written by a practitioner in the field. This idea will appeal especially to botanists who teach courses in biology, since even the best of the currently available biology textbooks scarcely deal adequately with the plant way of life.

Another and possibly greater merit of the series is that it offers something between the bare-boned paperback course outline type of book and the magnificent textbooks-to-end-all-textbooks that have become elaborate and expensive beyond the bounds of reason and seem intended to substitute for teacher, library, laboratory, and even field trip.

In the 106 text pages of THE PLANT KINGDOM Dr. Bold has given a summary account of all the major groups of plants. The accounting is complete in that there is something about everything; but in such a concise synopsis there can not be much about anything. Of the ten chapters into which the book is divided, a brief introduction presents the different schemes of classification and discusses the diversity within unity of the plant world. Another chapter describes the structure of vascular plants, including ontogenetic development from apical meristems. Other chapters discuss the various groups from Algae to Angiosperms. The final chapter is a summary, in a scant nine pages, of the vegetative bodies, reproduction, evolution, and classification of the wide array of members of the plant kingdom. There is an index and an annotated reading list of six substantial book titles.

Illustrations, including both line drawings and photographs, occupy about a third of the page space. These are clear and well chosen and include some that this reviewer has not seen elsewhere. Their major shortcoming is a lack of any indication of scale, high power photomicrographs being presented next to habit sketches with no hint to the reader that one structure is actually hundreds of times as large as the other.

This slim volume will not substitute for an imaginative and well informed teacher; but it will serve admirably as a reference source of factual information, leaving the elaboration of ideas, documentation with evidence, and general fleshing out with interesting details to be done in laboratory and classroom as the individual teacher sees fit.—BETTY F. THOMSON, Connecticut College, New London.

The Sloane Herbarium. By J. E. Dandy. 1–246. *Frontisp., pl. 1, 2 + 31 unnumb.* British Museum (Natural History). 7 Apr 1958.

This is an important reference for the taxonomist and of considerable interest to the historian of science. Sir Hans Sloane was one of the founders of the British Museum, and his collections, with those of Sir Joseph Banks, formed the nucleus of the herbarium of that institution. The "Herb. Sloan." consists of an estimated 120,000 specimens in 337 numbered *horti sicci*, bound (as was the custom of the time) in 265 volumes. Besides plants collected by Sloane himself in Jamaica and elsewhere, there are specimens from most of the well-known collectors of the seventeenth and early eighteenth centuries, as Bartram, Miller, Boerhaave, Kaempfer, Petiver, Plukenet, Cunninghame, Catesby. Sloane was in touch with Ray, and many specimens are named in accord with the *Historia* of that great botanist. Linnaeus visited the herbarium, finding it " in complete disorder" (and incapable of being rearranged in a system as loose sheets could have been). The collection thus furnishes an invaluable example of the state of botany and of botanical methods just before the Linnaean period. Moreover many specimens are important as the bases (direct or indirect) of descriptions of species by Linnaeus and others. (Whether such specimens are types is perhaps questionable. Plate 1 shows a specimen said to be the type of *Sloanea emarginata* Linnaeus; but the description in the *Species plantarum* cites only Catesby's description and plate, which were founded on the specimen, and it remains to be shown that Linnaeus saw the specimen itself.)

The detailed information on the provenance of the *horti sicci* is based on notes by James Britten and others, made over many years, and now collated, edited, and supplemented by the Keeper of the Herbarium of the British Museum. Besides a preface by Dandy, there are introductions by Spencer Savage and by Britten. Part 1 (pp. 27–78) contains an annotated list of the *horti sicci*. Part 2 (pp. 81–231) consists of biographical accounts of those who contributed to them. There are indexes to places and to botanical names. Not the least interesting part of the book is the collection of handwritings reproduced on 31 plates, with an index.—H. W. RICKETT.

Note

Resignation of Mrs. Lazella Schwarten

Those who use the "Index to American Botanical Literature" will have noticed a new name on the masthead. Dr. Clark Thomas Rogerson, Curator of Cryptogams at The New York Botanical Garden, has succeeded Mrs. Lazella Schwarten, Librarian of the Gray Herbarium and Arnold Arboretum, as compiler and editor of this department of the Bulletin.

The "Index" has appeared regularly since 1886; some notices of current literature were included even in volume 1 (1870). This useful compilation has been made by many persons over these many years. Mrs. Schwarten, as Bibliographer of the Club, carried the burden from 1940 to 1960, when she resigned. During this period the number of serials indexed was substantially increased; and the titles were for the first time grouped in a botanical classification. Because of the war the turnover of collaborators was high and most of the indexing was done by the Bibliographer herself, with the assistance of the Bibliographer of The New York Botanical Garden. In spite of this increase in the load, the "Index" reached a high point in accuracy and inclusiveness.

Mrs. Schwarten has earned the gratitude of the Club for her long and faithful service.

INDEX TO AMERICAN BOTANICAL LITERATURE

COMPILED BY

CLARK T. ROGERSON

WITH THE COLLABORATION OF

LAZELLA SCHWARTEN, H. W. RICKETT, AND HERMAN BECKER

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